EWE NUTRITION AND LAMB GROWTH

by

C Fiona S Clark
BSc (Hons) Agriculture

A thesis submitted for the degree of

Doctor of Philosophy

The University of Edinburgh

October 1983

ABSTRACT OF THESIS

1. The literature review initially describes foetal and placental growth and development. The following two sections present the effects of nutrition before mating and in early pregnancy, concentrating mainly on the effect on ovulation and lambing rate, and identify the lack of information on the effect on foetal lamb growth and birth weight.

2. Aspects of nutrition, particularly during mid and late pregnancy are reviewed. The close relationship between energy and protein nutrition is recognised in relation to foetal growth.

3. Finally, an account of nutritional effects on lactation is given and again emphasising the role protein and energy have to play. Methods of assessing milk yield are also described.

4. The first experiment provided information on differences in maternal body composition, early foetal and placental growth and development brought about by high and low planes of feeding for ten weeks before mating and up till 90 days of gestation. The foetus weights were not different, but placenta and cotyledon weights were heavier ($p < 0.05$) for better nourished ewes. Liveweights of ewes differed by 27 kg, but energy contents differed by 479 MJ, or poorly fed

ewes had half the reserves of well fed ewes.

5. The second experiment provided information on changes in body composition as a result of high and low levels of nutrition before mating. Ewes received different amounts of protein and energy in late pregnancy. Maternal body changes as well as the growth of foetuses and placentae were followed throughout this period. As in the first experiment the changes in energy were greater than would have been predicted from liveweight changes. Maternal composition was largely affected by treatment before mating. Lambs from ewes on high protein levels were approximately 1 kg heavier than lambs from ewes on low protein irrespective of energy level. Little effect was observed on the placenta as a result of treatment, but it increased in weight between 90 and 142 days of gestation.

6. The third experiment provided information on the effect of increasing increments of fishmeal inclusion in the concentrate ration on ewe weight, milk yield and lamb birth weight and growth rate. The milk yield and growth rate recording ceased after four weeks of lactation. There was a significant difference of about 2 kg in the weight of twin lambs from ewes receiving concentrates with 0.15 and 0.2 fishmeal compared with those receiving barley alone. By weaning, after grazing on pasture, no differences

in lamb weight were evident.

7. The results are discussed in the light of current research information and in relation to commercial practice.

DECLARATION

This is to declare that this thesis has been composed by myself and has not been accepted in any previous application for a degree. The work of which it is a record has been done by myself and all sources of information have been specifically referenced.

All help given by other people is indicated in the acknowledgements.

C Fiona S Clark

CONTENTS

ACKNOWLEDGEMENTS

I wish to sincerely thank Dr Andrew Speedy, now at the University of Oxford, for supervising the work and for his encouragement, patience and practical help given throughout this study.

I am also grateful to Professor John Prescott, of the Edinburgh School of Agriculture for the provision of the research facilities and for his support in this work.

I am indebted to the Meat and Livestock Commission for a postgraduate scholarship.

Sincere thanks are due to staff at the Sheep Unit, Bush Estate, in particular, Mr Jack FitzSimons, Miss Annette Sanderson, Miss Kathy Morris and Mr Malcolm Hutchinson for help with the feeding, care and transport of the animals.

For technical help in the processing of the carcasses I wish to acknowledge the help of Mr J. Fraser and the staff of the Carcass Evaluation Unit, and Dr A.W. Illius and other willing helpers. The analytical work of Dr P. Crooks and the Central Analytical Laboratories was greatly appreciated. I also wish to thank Dr A.R. Henderson and her staff for the use of facilities at Bush.

The advice and help of Miss P. Phillips in the statistical analysis and in the latter stages, Mr A. Hunter and Mr R. Evans, all of the Agricultural Research Council Unit

for Statistics, is gratefully acknowledged.

I should like to thank the staff at Gorgie Abattoir, Mr Ben Mitchell and staff at the Moredun Institute for their help and co-operation in the slaughter work. Also the post-mortem and cold storage facilities at the Veterinary Investigation Laboratory, the East of Scotland College of Agriculture were appreciated.

Thanks are due to Mr J. Fraser and staff of the Royal (Dick) School of Veterinary Medicine for their patience and help in X-ray photography of the sheep.

I am deeply grateful to Mrs Caroline Varley for her rapid typing of this thesis and to my husband, Garth, for his presentation of the figures.

Finally, I wish to thank sincerely the many friends without whose encouragement and faith throughout the period of study this thesis would not have been completed.

ABBREVIATIONS

AAN	amino acid nitrogen
App. dig. N	apparently digested nitrogen
CP	crude protein
DCP	digestible crude protein
DM	dry matter
FFA	free fatty acids
ME	metabolisable energy
N	nitrogen
RDP	rumen degradable protein
UDP	undegradable dietary protein
W	liveweight
g	grammes
kg	kilogrammes
MJ	megajoules

Statistical terms

Sig.	Levels of significance
NS	not significant
*	$p < 0.05$
**	$p < 0.01$
***	$p < 0.001$
CV	coefficient of variation
SE diff.	standard error of the difference

INTRODUCTION

One of the principal criteria for a successful sheep enterprise is the production of viable lambs. Lamb rearing rates of 1.43 and 1.49 for average and top third lowland flocks and 1.32 and 1.36 for average and top third upland flocks (MLC, 1982) suggest that there is scope for improvement. To minimise losses from birth to rearing it is important that lambs should be born with an adequate birth weight, energy reserves and a good milk supply since the majority of early lamb losses can be accounted for by chilling and starvation. The achievement of these objectives is largely determined by ewe management and nutrition. The Meat and Livestock Commission (1982) showed that in lowland and upland flocks the top third of producers used 2 kg less concentrates than average producers. This implies that the way in which concentrates are fed is important. It is also possible that strategic manipulation of ewe body reserves plays a role in the profitability of the system.

Current recommendations for premating management of ewes is to aim for good condition and a rising plane of nutrition in order to obtain optimum ovulation and conception rates. Speedy, Black and FitzSimons (1983) have suggested that ewe weight at mating also affects lamb birth weight over and above the effect of late pregnancy feeding. Therefore the first hypothesis to be tested was that premating and early pregnancy nutrition influences foetal growth and development and hence lamb birth weight.

Energy nutrition of the ewe during pregnancy and lactation has received most attention, but recently it has been suggested that protein may have a more important role to play. The second hypothesis was that protein level in late pregnancy and lactation has an effect on foetal growth, lamb birth weight and milk yield.

In testing these hypotheses measurements of ewe liveweight, maternal body composition and conceptus growth and development have been carried out.

CHAPTER 1
FOETAL GROWTH

1.1 Weight-age growth equations

In the nineteen thirties to forties allometric equations of the form $y = ax^b$ (where y is the weight of a component, x represents the whole body or a reference component, and a and b are constants) were thought to best describe growth. Brody (1945) explained that this relationship could be applied to data from many species which formed a linear trend when plotted on a log-log axis. Prenatal growth was considered to be an early part of the whole growth curve which continued, uninterrupted, into the postnatal period (Brody, 1945). The uterine environment may limit the later growth of the foetus as Cloete (1939) recognised. His data showed a short growth cycle with a self-accelerating and self-retarding phase. The latter end of the curve (1) rose too steeply and the observed data fell to the right of it.

(1) $\log_e y = 9.2169 \log_e t - 0.4652(\log_e t)^2 - 25.8778$

y = foetal growth (g) t = gestational age (days)

In relating foetal weight and age, Joubert (1956) divided the curve into five segments of age in order to fit allometric equations (2 to 6).

(2) 18 - 45 days $W = 0.0024716e^{0.18806t}$

(3) 46 - 60 days $W = 0.053087e^{0.11870t}$

(4) 61 - 74 days $W = 1.9590e^{0.06228t}$

(5) 78 - 109 days $W = 6.260e^{0.04892t}$

(6) 110 - 147 days $W = 75.918e^{0.02732t}$

W = foetal weight t = days of gestation

One equation was not enough to describe growth over the whole of gestation, because of the constantly changing specific growth rate.

The dynamics of embryonic growth were studied by Laird (1966) and he, and later Robinson, McDonald, Fraser and Crofts (1977) found that the Compertz equation (7) minimised residual standard deviation in describing foetal growth. It also satisfied the criteria that parameters of the equation could be interpreted in simple biological terms and that realistic extrapolations could be made outwith the range of the data (Robinson and McDonald, 1979).

(7) $\ln(Y) = 2.419 - 17.574e^{-0.01976t} - 0.00079ft + 0.0046W$

Y = foetal weight t = days of gestation f = litter size
W = weight of the ewe at mating

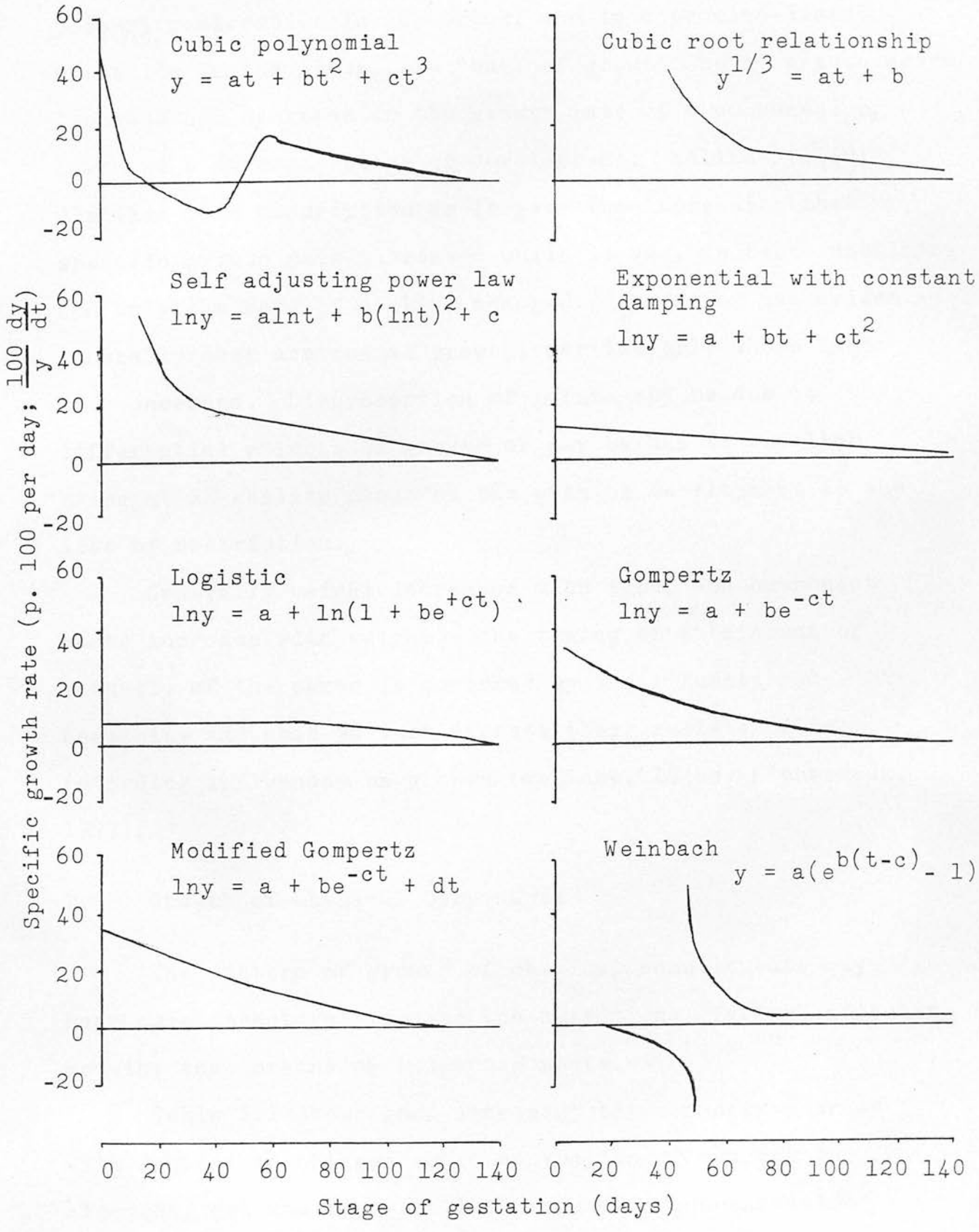
Figure 1.1 shows a range of equations which estimate specific growth rates throughout gestation. In most it is clear that the foetus starts with a high specific growth rate which declines towards term.

Equation (7) had the advantage of being applicable within and between species. Elsley, MacPherson, Ball and Pirie (1968) applied it to foetal pig growth and found that the equation fitted the curvilinear body weight increase. It can be used in comparison with growth work with sheep and other animals.

1.2 Anatomical Growth

Early workers estimating nutrient requirements for pregnancy were concerned with the timing of restricted periods of nutrition and their differential effect on high quality carcass joints which might be at their maximum specific growth

Figure 1.1 Specific growth rates throughout gestation from a range of equations that have been fitted to data obtained during the last 12 weeks of gestation



Source: Robinson and McDonald (1979)

rate at the time of restriction. This follows from the Hammond school of thought (Hammond, 1932) which said that a "wave of growth" passes through the animal in an anterior-posterior direction in the trunk, and in a proximo-distal direction in the limbs, the "wave of growth" being a successive increase and decrease in the growth rate of a component or organ at a discrete stage of development. Wallace (1948) disliked this description as it gave the impression that specific growth rate increased while it was, in fact, declining and only the rate of decline changed. Confusion has arisen generally over anatomical growth, particularly where lambs are concerned. Disproportion of joints may be due to differential effects on growth or may be due to the lamb being at an earlier stage on the path of development at the time of restriction.

Generally weight increases with time, and component parts increase with weight. The timing of attainment of maturity of the parts is governed by their functional necessity and this in turn affects their resistance to retarding influences on growth (Wallace, 1948c; Richardson, 1977).

1.3 Growth of Chemical Components

The pattern of growth of chemical constituents may bear more direct relation to the nutritional factors affecting growth, than organs or body components.

Table 1.1 shows good agreement between data sources with respect to changes in concentration of components. Fat, nitrogen, ash and energy all increased in concentration between 90 days and term, while water decreased. This is

Table 1.1 Chemical composition of ovine foetuses (g/kg)

Source	Stage of gestation days	Breed	Fat g/kg	Water g/kg	Ash g/kg	Nitrogen g/kg	Energy MJ/kg
Wallace* (1948)	84	Suffolk x Halfbred	6.2	913	-	-	-
	112		28.3	858	-	-	-
	140		32.9	822		-	-
Langlands & Sutherland (1968) predicted	90	Merino	4.8	883	22.2	9.9	2.20
	125		22.1	804	33.5	19.8	4.01
	145		26.0	786	36.0	22.1	4.40
Rattray, Garrett, East and Hinman (1974)	70	Suffolk x Targhee	5	904	19	10	1.88
	100		15	857	25	15	2.97
	125		21	893	27	18	3.60
	140		21	817	30	20	3.89
McDonald, Robinson, Fraser and Smart (1979)	< 85	Suffolk x (Finn x Dorset)	8.9	899	17.1	11.2	-
	90-98		12.3	870	24.1	14.6	-
	105-133		21.0	827	29.4	18.7	-
	135-145		21.9	800	34.6	22.7	-

the pattern expected in growing animals, but lambs still have a relatively high water concentration at birth with only 0.20 dry matter compared with about 0.40 in the adult.

The absolute weight of constituents is given in Table 1.2 but additional amounts of nutrients are laid down in the adnexa and must be accounted for in the maternal pregnancy allowance.

1.4 Genetic

The growth of the foetus is determined by its own genotype, the genotype of the dam (Hafez, 1963) and the various genotypes of the litter mates mediated by intrauterine competition (Beatty, 1960). The dam effect is more important than the sire, accounting for 50-75% of the variability in foetal size (Lush, Hetzer and Culbertson, 1934). Gregory and Castle (1931) found differences in size due to breed occurring as early as 41 hours in the rabbit. These differences may be attributed to different amounts of a special substance of the sulphydryl group in the embryo (glutathione), whose availability may limit foetal weight (Gregory and Goss, 1933a, b, c).

In sheep, Donald and Purser (1957) and Donald and Russel (1970) found that as breed weight increased, the proportion of maternal weight at mating formed by birth weight declined (Table 1.3 and Figure 1.2). The larger breed sizes, for example, the Oxford, had smaller lambs in relation to their own body weight compared with Blackfaces (Table 1.3). This also applied to the relationship between metabolic body weight (Table 1.4).

Table 1.2 Weight of ovine foetal chemical constituents

Days of gestation	Total kg *	Fat g	Water g	Ash g	Nitrogen g
90	0.707	8.7	636	17.0	10.3
125	2.945	61.8	2436	86.6	55.1
140	4.211	92.2	3369	143.7	95.6
146	4.719	103.3	3775	163.3	107.1

Foetal wt calculation using Gompertz equation

$$\ln (Y) = 2.419 - 17.574e^{-0.01976t} - 0.00079ft + 0.0046W$$

Y is foetal wt t is days of gestation f is litter size

W is wt of ewe at mating.

t = 2 W = 75

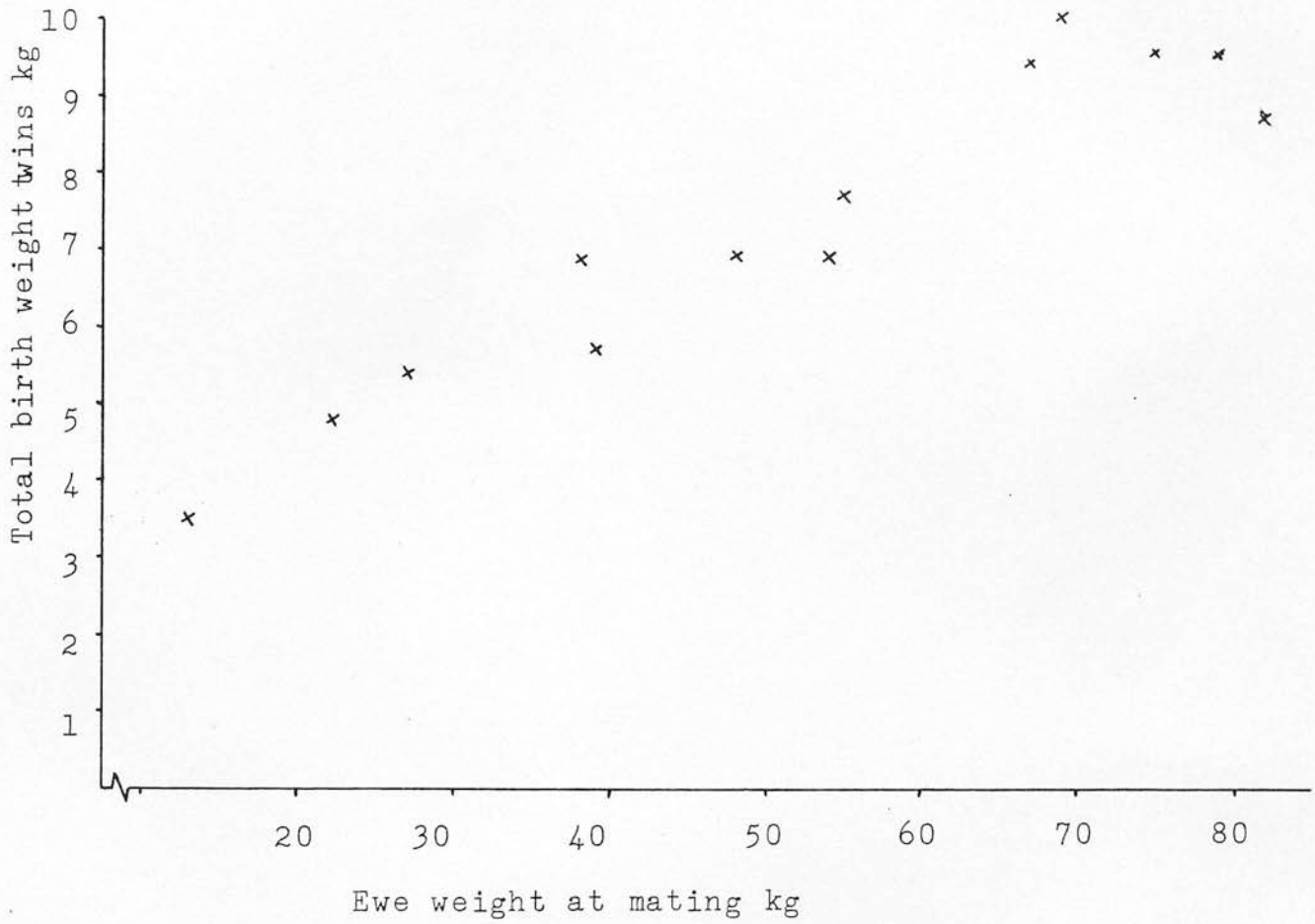
(Source: Robinson, McDonald, Fraser and Crofts, 1977).

Table 1.3 Mean weights of ewes at mating (kg) and twin lambs (kg) at birth (for ewes at second parity or more).

Breed	No ewes	Ewe wt	Litter wt	Wt of 1 lamb / Wt of ewe
Soay	14	23	3.5	0.08
Welsh Mountain	546	32	4.8	0.08
Shetland	2	37	5.4	0.07
Finnish Landrace	17	49	5.7	0.06
Tasmanian Merino	2	47	6.7	0.07
Scottish Blackface	76	58	6.9	0.06
Swaledale	40	48	6.9	0.07
South Country Cheviot	34	65	7.7	0.06
Southdown	6	64	6.9	0.05
Wiltshire Horn	10	79	10.0	0.06
Clun Forest	60	77	9.4	0.06
Suffolk	21	85	9.5	0.06
Border Leicester	6	92	8.7	0.05
Lincoln Longwool	12	89	9.5	0.05

Source: Donald and Purser (1956).

Figure 1.2 Relationship between birth weight of twins with mating weight of different breeds of mature ewes.



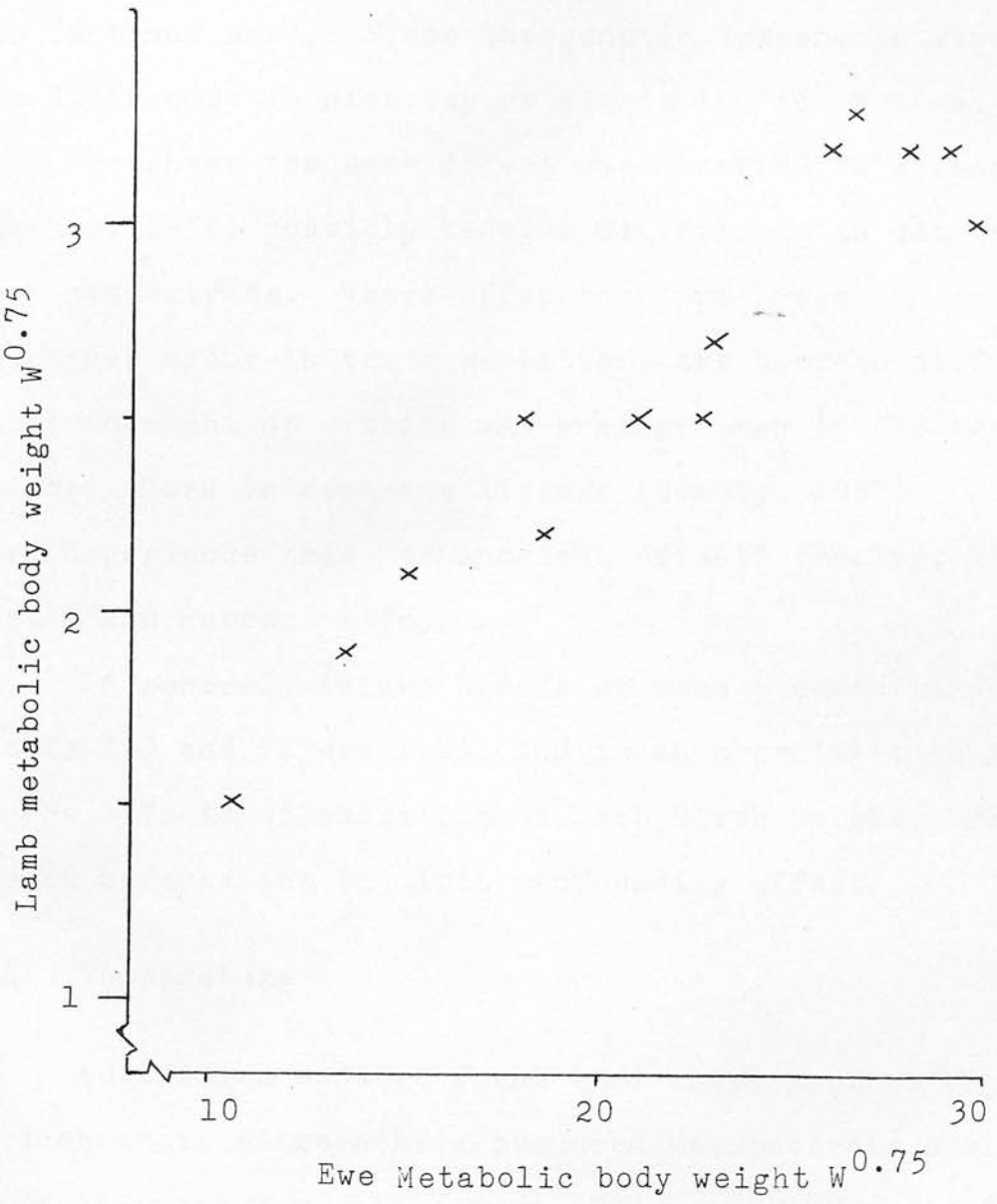
Donald and Purser (1956)

Table 1.4 Metabolic body weights of ewes at mating and lambs at birth. Metabolic body weight $W^{0.75}$ kg.

Breed	Ewe	1 twin lamb	$\frac{\text{Lamb wt } W^{0.75}}{\text{Ewe wt } W^{0.75}}$
Soay	10.5	1.5	0.14
Welsh Mountain	13.5	1.9	0.14
Shetland	15.0	2.1	0.14
Finnish Landrace	18.5	2.2	0.12
Tasmanian Merino	18.0	2.5	0.14
Scottish Blackface	21.0	2.5	0.12
Swaledale	18.2	2.5	0.14
South Country Cheviot	22.9	2.7	0.12
Southdown	22.6	2.5	0.11
Wiltshire Horn	26.5	3.3	0.12
Clun Forest	26.0	3.2	0.12
Suffolk	28.0	3.2	0.11
Border Leicester	29.7	3.0	0.10
Lincoln Longwool	29.0	3.2	0.11

Calculated from Donald and Purser (1956)

Figure 1.3 Relationship between metabolic body weight $W^{0.75}$ of ewes at mating and lambs at birth



Donald and Purser (1956)

1.5 Dam Effects

Maternal size effects on birthweight were best demonstrated by Walton and Hammond (1938) when they made reciprocal crosses with Shetland and Shire horses and compared foal sizes. The foal from the Shire mare was 0.5 heavier than the foal from the Shetland mare. Since the genetic components were the same, the difference in size may be attributed to the dam.

In sheep the same effect was observed to a lesser extent (Hunter, 1956) possibly because differences in dam weight were not extreme. Where offspring from large and small genotypes occur in the same litter, the average difference in birthweight of rabbits was greater than if the two types had been born in separate litters (Beatty, 1957). Sheep also experience this "enhancement effect" (Beatty, 1956; Donald and Purser, 1956).

In general, larger breeds of ewes produce larger lambs (Table 1.3 and Figure 1.2), and in an experiment to look at the effects of nutrition on lamb birth weight, breed should be constant to limit confounding effects.

1.6 Temperature

Australian workers found that sheep kept at high environmental temperatures produced unexpectedly small lambs (Alexander and Williams, 1971). The "dwarfing" was greater than could be accounted for by reduced maternal intake. Yeates (1958) also discounted a simple nutritional effect, when he found that the livers of small lambs were disproportionately large. However a reappraisal of the data by Cartwright and Thwaites (1976c) showed that the Yeates'

large liver was due to one unusual lamb in the group. They concluded that the lambs showed symptoms of extreme nutritonal deprivation, both in physical size and lack of maturity of secondary wool follicles. The effect was associated with small placentae and calculation of the energy balances (Blaxter, Wainman and Graham, 1959), revealed that increased maternal maintenance requirement due to high temperature altered partitioning of nutrients resulting in a starved foetus.

The application of the phenomenon in temperate climate arises on housing ewes. Densely stocked sheep in an enclosed space raise the environmental temperature. Heat stress may become a problem if temperature rises to a level where maternal maintenance requirements are increased for heat dissipation (due to panting and operation of heat dissipation mechanisms). A number of workers have clipped ewes on housing. Austin and Young (1977) and Vipond (1979) found significant improvements in birth weights without any detrimental effect due to clipping.

The effect of heat stress on lamb birth weight appears to be due to impaired foetal nutrition, not because of reduced maternal intake, but because of increased maternal maintenance demands and a change in the partitioning of nutrients.

CHAPTER 2

THE PLACENTA

2.1

The placenta consists of the amniotic, chorionic and allantoic membranes and the cotyledons, which are highly vascular structures on the chorionic membrane. These fit into specific areas in the uterine lining known as cotyledonary burrs or caruncles. The foetal cotyledons are linked by a network of blood vessels leading to the umbilical cord of the foetus. The development of the cotyledon starts on day 16 of gestation when the trophoblast fills the lumen of the uterus and comes into contact with the caruncles (Robinson, 1982). In multiple litters there are no placental anastamoses in sheep. Each foetus is separately contained in its own membrane sac. Careful examination of the membranes reveals a fine white line, distinct from blood vessels, which divides adjacent foetuses (Stegeman, 1974).

The importance of placental growth lies in its correlation with foetal weight (Stegeman, 1974). As it is the means by which the foetus receives its nutrient supply, its size may affect that supply.

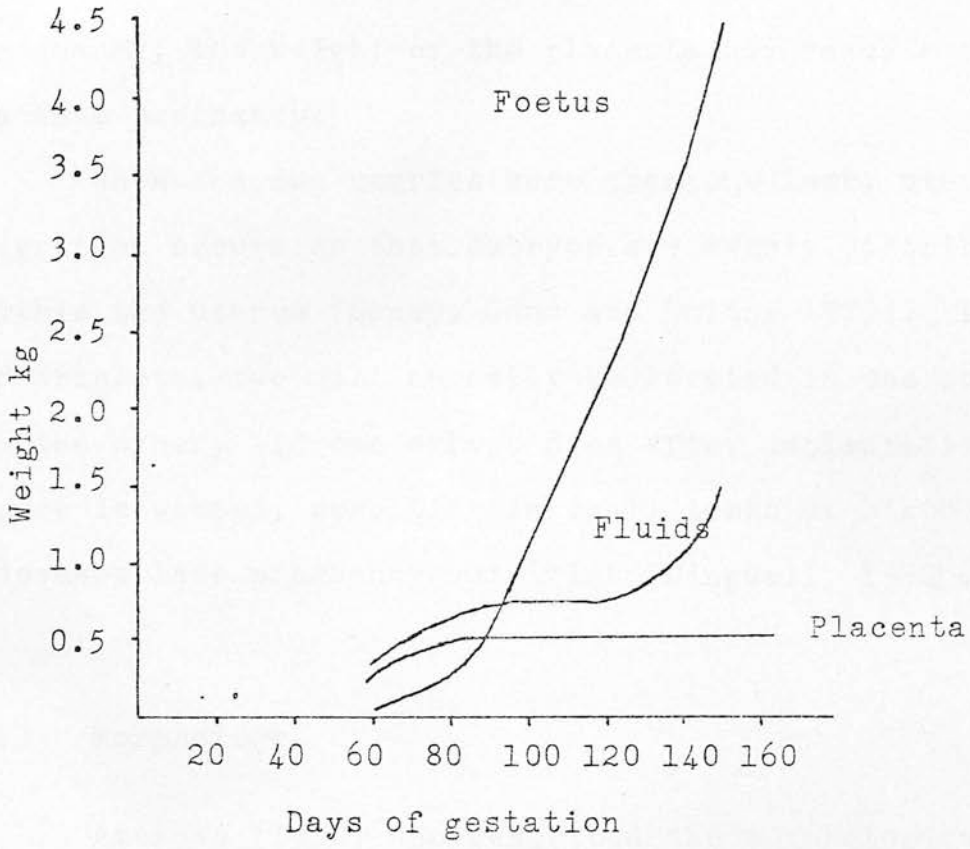
2.2 Placental Growth

Robinson, McDonald, Fraser and Crofts (1977) have described the growth of the placenta mathematically by the equation:

$$\ln(\text{placental weight per foetus kg}) = -0.387 - 245.171 \exp(-0.1007t) - 0.119f$$

Residual standard deviation = 0.17 where t = days of gestation f = number of foetuses. This is illustrated in Figure 2.1.

Figure 2.1 The mean weight of each of twin foetuses and their placenta and fluids at different stages of gestation in ewes of approximately 70 kg at mating



Source: Robinson (1980)

Much of placental growth is achieved in the mid pregnancy period, and weight remains relatively constant from 90 days of gestation onwards. Cloete (1939) recorded that placental weight actually declined in the last two months of pregnancy, although Stegeman (1974) suggested that the human placenta continued to gain in weight throughout pregnancy. The latter may be explained by the fact that all material examined would have been obtained from naturally premature births, which may have been caused by small placentae. In a normal pregnancy, the weight of the placenta may reach a plateau in late pregnancy.

When the ewe carries more than one lamb, uterine migration occurs so that embryos are evenly distributed within the uterus (Doney, Gunn and Smith, 1973). In the case of triplets, two will normally be located in one horn and one in the other. If one embryo dies after implantation, its space is wasted, resulting in small lambs at birth despite adequate late pregnancy nutrition (Dingwall, 1982).

2.3 Morphology

Amoroso (1952) has described the morphological aspects of placental development which help to explain the way in which certain features of the vascular architecture are important in determining the nutrient supply to the foetus.

The fertilised ovum travels down the fallopian tubes to the uterus, and begins to implant on about day 15 of gestation. On the 17th day the surfaces of the maternal cotyledonary burrs degenerate and are replaced by bi-nucleate cells of the foetal ectoderm. Before that, there is loose

attachment of the membrane to the caruncle. On the 31st day, villi appear on the surface of the chorionic sac surface which leads to a closer attachment. The uterine epithelium is destroyed, firstly by bi-nucleate and later by phagocytic cells. Erosion occurs, both in the cotyledonary burrs and the intercotyledonary spaces. Cotyledon surfaces are covered with large globular cells.

Villi develop as buds of foetal ectoderm in cotyledonary areas of the trophoblast, which later contain mesoderm with branches of allantoic vessels. The trophoblast assumes an "archway" like structure between the villi buds. Blood vessels are found in the centre of villi, which fit into depressions on the surface of the maternal cotyledons, increase in length and branch in different directions as pregnancy advances.

In a normal pregnancy cotyledon weight will be related to foetal weight, but in the event of placental growth being restricted, the placenta has the capacity to compensate by increased vascularisation and blood volume (Stegeman, 1974). Another factor which acts as a compensatory mechanism is the branching of the villi which increases total villous area. These are some ways in which the ewe can buffer the growth of the foetus when conditions have restricted placental growth. In addition, Everitt (1968) has reported early infarction of foetal cotyledons where there is a restricted nutrient supply. This increases the ratio of foetal:maternal contact area.

2.4 Placental Function in Relation to Foetal Growth

The main function of the placenta is to provide a nutrient supply for the foetus, although from day 60 it

has a hormonal role, through the production of progesterone, in maintenance of pregnancy independent of the corpus luteum (Huggett and Hammond, 1952).

2.5 Factors Affecting Placental Growth

Severe undernutrition of the ewe leads to a reduction in the weight of the cotyledons (Everitt, 1964) and this is associated with reduced foetal weight (Table 2.1).

Male lambs tend to have heavier placentae than female lambs and are usually heavier at birth. When for some reason, placental growth is restricted, the male lamb fails to achieve its normal potential (Stegeman, 1974).

Heat stress reduces cotyledon weight as it does birth weight. The placenta has been observed to actually shrink in size. This phenomenon is thought to be associated with diversion of the blood supply to the peripheral circulation for temperature regulation (Alexander, 1974).

2.6 Consequences of Restricted Placental Growth

Everitt (1968), among others, has emphasised the importance of placental sufficiency to avoid restrictions in foetal growth. Alexander (1964a) noted the relationship between birth weight and weight of intact cotyledons and of foetal cotyledons, and proceeded to show that, when various numbers of caruncles were removed surgically, birth weight was reduced (Alexander, 1964b). There was some compensation in terms of heavier individual functional cotyledons, though total functional cotyledon weight was not wholly made up. Birth weight was related to total functional cotyledon weight rather than numbers of cotyledons. Compensation

Table 2.1 Effect of heating and undernourishing pregnant ewes on birth weight and placental weight.

	Treatment of ewes during pregnancy		No of ewes	Birth wt kg	Weight of cotyledons	
	Mid third	Last third			g	% foetal
Series 1	Nil	Nil	7	3.62	377	32
	Heat	Heat	9	1.79	120	34
	Underfed	Underfed	11	2.44	393	39
Series 2	Nil	Nil	5	3.23	423	45
	Heat	Heat	5	1.63	139	40
	Heat	Nil	5	2.45	288	43
	Nil	Heat	4	2.29	251	50

Source: Alexander and Williams (1971)

probably occurred through increased vascularisation, though this was not measured. Everitt (1968) suggested that there was probably some critical threshold weight for the placenta below which foetal growth and development is limited.

Nutrition can affect placental growth and development. Everitt (1968) discussed work where restricted growth in early life resulted in retardation of post-natal growth and limited mature size (Taplin and Everitt, 1964; Everitt, 1967).

Lambs born with a low birthweight are likely to be less viable and have a lower content of brown fat, which is important for temperature regulation in very early life.

In conclusion, placental weight is correlated with foetal weight and factors, which reduce the former, restrict the potential of the latter. Nutrition is one such factor. Compensatory mechanisms within the placenta do exist, but when development is restricted below a critical threshold, birth weight, lamb energy reserves, and viability are likely to be affected.

CHAPTER 3

PRE-MATING NUTRITION AND EWE PRODUCTIVITY

3.1

Reproductive performance of ewes is determined by ovulation rate, fertilisation and embryo and foetal survival. Most studies on pre-mating nutrition have been concerned with the effect on ovulation rate.

Coop (1966) showed that the effects of pre-mating nutrition on ovulation and lambing rate, could be separated into the static effect of body condition of the ewe, and dynamic effect of plane of nutrition.

Later work at the Hill Farming Research Organisation (Gunn, Doney and Russel, 1969) showed differences in response between genotypes, the Scottish Blackface being more responsive than the North Country Cheviot which in turn showed a greater response than the South Country Cheviot. The Finn x Blackface showed virtually no response but ovulation rate was uniformly high.

3.2 Effects of Body Condition on Ovulation and Lambing Rate

Table 3.1 summarises a number of reports on the effect of body condition at mating on ovulation and lambing rate. Comparisons between sources are difficult to make because of differences in breed, ewe size and conditions. Within sources, it is evident that ewes in better condition or with a high liveweight at mating, had a lower incidence of barrenness (Coop, 1964; Cumming, Rizzoli, Clarke and McPhee, 1978), a higher ovulation rate (Bramley, Denehy and Newton, 1976;

Table 3.1 The static effect of liveweight or body condition on ovulation rate and lambing rate of ewes.

Source	Breed	Live weight	C.S.	Proportion of barren ewes	Ovulation rate	Lambing rate
Coop (1964)	Corriedales and Romney	66		0.062		1.57
		57		0.043		1.38
		65		0.033		1.68
		52		0.070		1.42
Bramley, Denehy & Newton (1976)	Masham	49.3	1.6		1.53	0.77
		63.7	2.9		2.13	1.50
		70.6	3.8		2.27	1.86
Cumming, Rizzoli, Clarke & McPhee (1978)	Border Leic. x Merino	63.5		0	1.86	1.75
		63.5		0.08	1.91	1.60
		51.8		0.20	1.76	1.22
MacKenzie & Edey (1975)	Merino	46.7			1.20	0.54
		40.3			1.24	0.73
		34.5			1.05	0.53
Fletcher (1971)	South Australian Long Woolled Merinos	54.9			1.43	
		49.3			1.30	
		43.5			1.13	
Gunn, Doney & Russel (1972)	Scottish Blackface	49.5	3		1.50	1.38
		60.7	3		2.21	1.50
		37.9	1.5		0.88	0.57
		46.4	1.5		1.31	0.50
Gunn & Doney (1975)	Scottish Blackface	57.5	3		1.93	1.28
		49.3	2.5		1.58	0.81
		48.5	2.5		1.64	1.32
		43.1	1.5		1.17	0.44
		39.3	1.5		1.00	0.36
Gunn, Doney & Smith (1979)	Greyface	68.0	2.8	0.18	2.32	1.50
		70.0	2.5	0.29	2.06	1.18
		62.2	1.8	0.18	1.82	1.36
		63.5	1.7	0.46	1.69	0.92

Cumming et al, 1978; MacKenzie and Edey, 1975; Gunn, Doney and Smith, 1979; Gunn, Doney and Russel, 1972) and a higher lambing rate (Coop, 1964; Bramley et al, 1976; Cumming et al, 1978; MacKenzie et al, 1975; Gunn et al, 1979; Gunn et al, 1972). The descriptions of body condition scores referred to are fully described by Russel, Doney and Gunn (1969).

Results obtained with Scottish Blackface ewes, presented by Gunn and Doney (1975) do not conform to the hypothesis completely but these results are confounded by the effect of different planes of nutrition before mating.

3.3 Effects of current plane of nutrition at mating

The dynamic effect, which is the direction of plane of nutrition before and during mating is illustrated in Table 3.2. Again, within sources, it can be seen that ovulation and lambing rate are increased on a rising plane of nutrition compared with a maintenance or falling phase. Where overall results are cited for one source the differences can be explained in absolute levels of condition.

The response is largely proportional to the duration of flushing (Allen and Lamming, 1961) or to the extent of liveweight or condition change (Bramley et al, 1976; Younis et al, 1978). Differences may also be influenced by the starting weight or condition of ewes prior to treatment (Fletcher, 1971; Gunn, Doney and Smith, 1979).

Fat ewes have often been associated with infertility in farming circles, which has given rise to the practice of taking ewes down in condition before flushing them. This association may have arisen because, ewes which were previously infertile became fat and failed to breed again in the

Table 3.2 The effect of plane of nutrition on ovulation and lambing rate of ewes.

Source	Breed	Ovulation Rate on Different Planes of Nutrition		
		Rising	Maintaining	Falling
Allen & Lamming (1961)	Clun Forest Kerry Hill	2.17 2.17 2.00 1.50 1.83 2.17		2.00 1.50 1.40 1.00
Coop (1964)	Corriedales Romney	(1.68) (1.69)		(1.49) (1.42)
Fletcher (1971)	South Aust. strong-woolled Merinos	1.45 1.27	1.42 1.33 1.10	1.29 1.26
Gunn & Doney (1975)	Scottish Blackface	1.64(1.32) * 1.00(0.86)	1.93(1.28)	1.58(0.81) 1.17(0.44)
MacKenzie & Edey (1975)	Merino	1.20		1.05
Bramley, Denehy & Newton(1978)	Masham	2.13(1.50) 2.27(1.86)		1.53(0.77)
Cumming, Rizzoli, Clarke & McPhee(1978)	Border Leic. x Merino	1.86(1.23) 1.91(1.19)		1.76(0.93)
Younis, Al-Kamali & El Tawil(1978)	Awassi	1.22 1.09 1.25	1.00	
Gunn & Doney (1979)	Greyface (Border Leic. x Scottish Blackface)	(1.96)	(1.78)	(1.58)

* Figures in brackets refer to lambing rates

following year, thus fatness and infertility are linked. Gunn, Smith, Senior, Barthram and Sim (1983) recently presented work which showed that ewes in very good condition at mating produced fewer lambs. This may be due to the fact that, initially ovulation rate was higher and, concomitant to that was a higher embryo loss as a result of declining plane of nutrition immediately after mating. Wallace (1961) showed that fat ewes per se did not result in a reduction in lambing rate (Table 3.3). Nutritional treatments were imposed to obtain the ewe weights at the start of flushing. Despite a weight loss in the fat ewes, lambing percentage was not detrimentally affected.

3.4 Breed differences

Certain breeds respond in different ways to the static and dynamic effects of flushing. For example, the Scottish Blackface shows a clear response to the static effect of body condition (Table 3.4), while being less affected by the dynamic plane of nutrition (Gunn, Doney and Russel, 1972; Gunn and Doney, 1975). The same workers found that the Cheviot responded well to a rising plane of nutrition (Gunn, Doney and Smith, 1979), but less well to absolute level of condition (Gunn and Doney, 1979) (Table 3.4). The Finn x Blackface, a prolific crossbred because of the Finn component, did not respond at all to increasing body condition score from 2 to 3 (Figure 3.1) (Doney and Gunn, 1973).

3.5 Hormones

Pregnant mares' serum is a natural crude preparation of follicle stimulating hormone (FSH) and luteinising hormone (LH)

Table 3.3 The effect of flushing on reproductive performance of fat ewes.

Treatment	Post-weaning weight	Start of flushing	Mating	No lambs/ ewe lambing	Lambing %
H	57.7	62.3	59.1	1.51	120
M	57.7	52.7	54.6	1.34	107
L	57.3	48.2	50.9	1.35	98

Source: Wallace (1961)

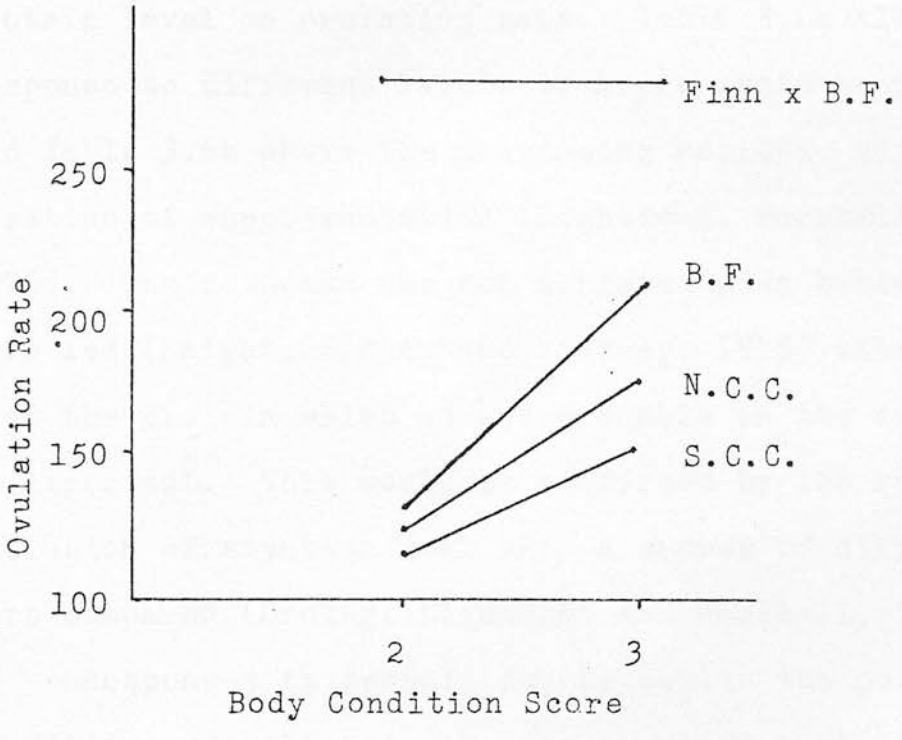
Table 3.4 Breed differences in response to the static and dynamic effects

	Liveweight	C.S.	Plane of nutrition	Ovulation rate	Lambing rate
Scottish Blackface	57.5	3.0	Maintaining	1.93	1.28
	49.3	2.5	Falling	1.58	0.81
	48.0	2.5	Rising	1.64	1.32
	43.1	1.5	Falling	1.17	0.44
	39.1	1.5	Rising	1.00	0.36
South Country Cheviot			Maintaining		
	54.9	2.95		1.46	1.21
	45.1	1.99	Maintaining	1.16	1.11
	49.0	2.5	Falling	1.21	1.12
	55.5	2.5	Rising	1.63	1.38

Source: Gunn and Doney (1979); Gunn, Doney and Smith (1979b)

Figure 3.1 The relationship between ovulation rate and body condition in different breeds of sheep

Finn. Finnish Landrace
B.F. Scottish Blackface
N.C.C. North Country Cheviot
S.C.C. South Country Cheviot



Source: Doney and Gunn (1973)

both secreted naturally from the anterior pituitary gland. FSH controls the maturation of Graafian follicles and the release of mature ova, while a peak of LH determines the time of ovulation

The preparation is used in practice, to induce multiple ovulation when ewes are being bred out of season. Allen and Lamming (1961) investigated the effect on ovulation rate and found that 600 i.u. of pregnant mares' serum increased ovulation rate in all groups (Table 3.5).

3.6 Protein nutrition

Australian workers have noted the effect of dietary protein level on ovulation rate. Table 3.6a illustrates the response to different levels of lupin grain supplementation and Table 3.6b shows the increasing response with increasing duration of supplementation (Lightfoot, Marshall and Croker, 1976). The response was not achieved when barley and urea were fed (Knight, Oldham and Lindsay, 1975) which suggested that the protein which is undegradable in the rumen might be important. This would be confirmed by the response to inclusion of soyabean meal when a number of different varieties were compared (Croker, Lightfoot and Marshall, Table 3.6c).

Responses to protein may be due to the poor nutritional conditions prevalent in the dry areas of Australia. Torell, Hume and Weir (1972) attributed only 7% of the flushing responses to protein compared with 61% due to energy.

In summary, responses have been observed in ovulation rate and lambing rate to improved body condition and rising plane of nutrition, but little attention has been given to the subsequent effect of these treatments on foetal growth and development and lamb birth weight.

Table 3.5 Effect of Pregnant Mares' Serum on ovulation rate at different lengths of flushing

Flushing time	Ovulation rate	
	No PMS	600 i.u.PMS
5-8 days	1.50	2.83
1 oestrous cycle	1.83	2.17
2 oestrous cycles	2.17	2.50
Submaintenance	1.00	2.40
Pooled	1.65	2.46

Source: Allen and Lamming (1961)

Table 3.6 Effect of level, duration and variety of lupin grain supplemntation on reproductive performance

	Ovulation rate	Lambing rate	Proportion of barren ewes
a. Level of lupin grain supplemntation g/d			
0	1.18	1.11	0.242
125	1.26	1.15	0.24
250	1.33	1.24	0.243
740 (*ad libitum*)	1.46	1.27	0.209
b. Duration of supplementation days			
0	1.21	1.11	0.249
7	1.38	1.24	0.208
14	1.38	1.22	0.278
Source: Lightfoot, Marshall and Croker (1976)			
c. Variety or treatment			
Nil (control)	1.13	0.84	0.25
Lupinus angustifolius cv Unicrop sweet	1.27	1.11	0.10
L. albus cv ultra sweet	1.33	1.05	0.20
L. cosentinii cv CB 46 sweet	1.30	1.06	0.16
L. cosentinii cv Chapman bitter	1.22	0.83	0.29
Pisum sativum	1.22	1.06	0.14
Soyabean meal pelleted	1.36	0.94	0.22
Source: Croker, Lightfoot, and Marshall (1978)			

CHAPTER 4

EARLY PREGNANCY NUTRITION AND EMBRYO MORTALITY

Following fertilisation, the embryo or embryos travel down the fallopian tubes and distribute themselves evenly throughout the uterine horns by intra uterine migration (Doney, Gunn and Smith, 1973). The process of attachment then begins at day 14 and is not complete until day 40 (Edey, 1969). It is while these tenuous links are being formed that the embryo is particularly vulnerable. Edey (1969) and Gunn, Doney and Russel (1972) have recorded the greatest losses the first 3-4 weeks of gestation.

4.1 Nutritional Effects

Nutritional effects on early embryonic loss are most easily observed through liveweight changes. Table 4.1 shows that, despite considerable losses in liveweight little effect was induced in the number of ewes pregnant although there was some evidence of embryonic mortality. This is explained by the reduction in numbers of twin-ovulating ewes with both ova surviving (Edey, 1966; Cumming, 1972a; Doney, Gunn and Smith, 1973). Kelly and Allison (1979) found no relationship between embryo losses and position of ovulation or transuterine migration, in contrast to Doney et al (1973) who showed that incidence of loss was higher when transuterine migration of embryos had occurred or when an embryo was situated in a horn with no associated corpus luteum.

Table 4.2 shows the significant effect of weight and body condition at mating on improving survival in North Country

Table 4.1 Effect of nutritional restriction in early pregnancy on number of ewes pregnant and embryo survival

Source	Breed	Nature of Restriction	Proportion ewes pregnant	Proportion embryos lost
Coop & Clark (1969)	Border Leic. x Corriedale	Maintained 5wks	0.96	
		Lost 4kg	0.98	
		Gained 2.6 kg	0.94	
		Lost 0.7 kg	0.95	
		Lost 0.7 kg	0.97	
		Lost 5 kg	0.99	
		Lost 0.5 kg	0.97	
		Lost 4.9 kg	0.97	
Bennett, Nadin & Axelsen (1970)	Merino	Loss 30% LW D1-60	0.82	
		Loss 30% LW D21-60	0.82	
		No restriction	0.83	
Gunn, Doney & Russel (1972)	Scottish Blackface	Good Condition: Losing 6% LW	0.12	
		Good Condition: Losing 12% LW	0.17	
		Poor Condition: Gaining 6% LW	0.63	
			NS	
		Poor Condition: Losing 6% LW	0.36	
Cumming (1972b)	Perendale	None		0.49
		Small area + 200g hay/d		
		Days 1-7		0.57
		" 8-14		0.53
		" 15-21		0.40
		" 1-14		0.53
		" 8-21		0.54
		" 1-7 &15-21		0.64
		" 1-21		0.53
Gunn, Doney & Smith (1979c)	South Country Cheviot	Gain 2.7-5 kg		0.14
		Loss 0.7-3.5kg		0.31

Table 4.2 Effect of body condition at mating on early embryonic loss

Source	Breed	Live weight	Condition Score	Proportion Loss
Gunn, Doney & Russel (1972)	Scottish Blackface	49.5	3	0.21
		60.7	3	0.10
		37.9	1.5	0.64
		46.4	1.5	0.38
Gunn & Doney (1979)	North Country Cheviots	64.7	3	0.18
		52.8	2	0.40
	South Country Cheviots	54.9	3	0.26
		46.1	2	0.24

Cheviot and Scottish Blackface ewes, but the effect was not evident in South Country Cheviots.

Some of the apparently negative effects of higher planes of nutrition on embryo survival (Gunn, Doney and Smith, 1979c) have arisen because improved nutrition increases ovulation rate and multiple ovulations show a higher incidence of mortality (Edey, 1976; Gunn, Doney and Smith, 1979b,c).

In a review Edey (1976) noted that this embryonic loss was only increased by severe undernutrition for one to three week during the first month of gestation.

4.2 Non-Nutritional Effects

4.2i Congenital defects Abnormal genetic material accounts for a proportion of the embryos which are lost (Bishop, 1964). Inbreeding reduces the number of ewes ovulating and increases in early mortality are evident due to the de novo lethal mutations (Edey, 1969).

4.2ii Ovulation rate As ovulation rate increases, a greater percentage of losses are evident (Henning, 1939; Gunn et al, 1972). This may be associated with an increase in trans-uterine migration (Casida, Pope and Woody, 1966; Doney, Gunn and Smith, 1973). The greater the number of embryos, the greater the chance of redistribution within the uterus, which has been associated with increased losses. It is also possible that limited uterine nutrient resources may increase loss when there are higher numbers of embryos.

4.2iii Age Ewe lambs (ie females less than 12 months) have been found to be more susceptible to embryo losses than ewes greater than 2 years (Edgar, 1962; Bennet Axelsen and

Chapman, 1964). Reproductive wastage was reported to be ·31 in ewe lambs compared with ·12 in mature ewes (Tyrell, Gleeson, Ferguson, O'Halloran and Kilgour, 1979). In addition, ·28 of ewe lambs which did not appear to return to service, ultimately failed to lamb, compared with ·06 of mature ewes in the same category (Tyrell, Gleeson, Ferguson, O'Halloran and Kilgour, 1979).

MacKenzie and Edey (1975a) induced a 0.45 ova wastage in ewe lambs on a 0.3 maintenance ration compared with 0.308 ova wastage in the control group. Mature ewes at the same liveweight had similar levels of ova wastage.

4.2iv Seasonal Effects Ewes bred away from the normal peak of the breeding season have sometimes been found to have a higher incidence of abnormal ova and embryonic deaths. Early breeding resulted in ·28.6 embryo mortality compared with ·09 9 later in the breeding season (Hulet, Voigtlander, Pope and Casida, 1956), while at the other extreme of the breeding season Laffey and Hart (1959) found ·40 of ova to be abnormal. Gunn, Doney and Smith (1979) recorded ·13 non pregnant ewes with 18 partial loss of multiple embryos for Greyface ewes mated in October compared with ·21 and ·20 respectively for ewes mated in November.

4.2v Heat Stress Thwaites (1967) found that continuous high temperature sufficient to raise rectal temperature by 2-3 ^{o}F increased embryonic mortality. Responses were modified by diurnal variation which would reduce the risk to ewes in hot climate in the field situation.

Table 4.3 Effect of exogenous progesterone administration on early embryonic survival

Progesterone mg/day	Survival Day 11 prop^{n}
Control	·83
5	·74
10	·76
15	·83
20	·92
25	·96
Significance	$p < 0.05$

Source: Parr, Cumming, Lawson, Kerton and Harris (1978)

Table 4.4 Effect on stress on embryonic survival

Treatment	Embryonic loss prop^{n}
Unstressed	·17 2
Environmental stress: Days 1-10	·29 9
Days 11-20	·29 0
ACTH treatment	·37 7

Source: Doney, Smith and Gunn (1976)

4.2vi Hormones High circulating levels of exogenous oestrogen resulting from ewes grazing oestrogenic red clover have been associated with reduced embryo survival (Moule, Braden and Lamond, 1963). Likewise the goitrogen content of kale has a detrimental effect on embryo survival (Williams, Hill and Alderman, 1965).

Low levels of progesterone have been observed to reduce embryo survival, but high levels were not detrimental (Parr, Cumming, Lawson, Kerton and Harris, 1978 (Table 4.3); Parr, Cumming and Clarke, 1982).

Stress associated with increased levels of adreno-corticotrophic hormone (ACTH) induced an almost two-fold increase in embryonic mortality (Doney, Smith and Gunn, 1976) which is shown in Table 4.4. Stress was imposed by six hours of rainfall per day.

4.2vii Effect of early embryonic losses on subsequent conception When a ewe has experienced early embryonic loss, subsequent pregnancies have a higher risk of failure. Tyrrel et al (1979) found that ·21 of returning ewes failed to lamb compared with ·06 of non-returning ewes. The corresponding figures for ewe lambs were ·36 and ·28. This may be caused by a physiological defect which recurs or it may, in part, be due to degenerating tissue in the uterus creating an unsuitable environment for implantation.

4.3 Early Pregnancy Nutrition

Apart from its influence on embryonic mortality early pregnancy nutrition may have some important implications for placental development (El-Sheikh, Hulet, Pope and Casida, 1955; Everitt, 1964). The foetus itself does not increase nutritional demands on the ewe at this time (Robinson, 1982)

but El-Sheikh, Hulet, Pope and Casida (1955) noted that the chorionic membrane was reduced in size as a result of a poor nutritional plane. Everitt (1964) also noted a reduced placental size at 90 days of gestation as a result of a low plane of nutrition. All these workers commented on the likely subsequent detrimental effects on foetal growth and development even if adequate late pregnancy nutrition was provided (Everitt, 1966, 1967).

4.4 Summary

In conclusion the main effects of early pregnancy nutrition are likely to be on embryo mortality and on placental growth and development, which may in turn influence foetal growth.

CHAPTER 5 ·

PREGNANCY NUTRITION OF THE EWE

5.1 Nutrients for the Products of Conception

The nutrition of the ewe during pregnancy is primarily concerned with the requirements of the foetus for growth. At birth the foetus consists of a mass of three to five kilograms, consisting of 0.82 water, 0.125 protein, 0.02 fat, 0.03 ash and with an energy content of 3.9 MJ/kg fresh weight (Rattray, Garrett, East and Hinman, 1974). In terms of total quantities of nutrients this does not represent a great deal compared with the daily nutrient requirements of the ewe in late pregnancy (Table 5.1).

Table 5.1 Ewe nutrient allowance and nutrient content of the foetus at birth

Nutrient	Content of 5 kg foetus at birth*	Daily Metabolisable energy requirements for 75kg ewe with 6 kg lamb +
Energy MJ	19.45	16.6
Crude protein g	625	130

* Calculated from Rattray et al (1974)

\+ Source: ARC (1980)

One foetus is not the only demand which the ewe must satisfy. Firstly, the lowland ewe frequently carried twins and sometimes triplets with associated increased requirements. Neither is the foetus the only tissue which grows during pregnancy. Closely associated with the foetus are placental

membranes with cotyledons, amniotic and allantoic fluid; the uterus itself increases in size and tissue is laid down in the mammary gland in preparation for lactation.

The data from different sources in Table 5.2 agree favourably, the lower values given by Langlands and Sutherland (1968) being accounted for by their exclusion of fluids and the fact that the ewes were only carrying one foetus. Considering a 70 kg ewe and Rattray's figure marked with an asterisk (Rattray et al, 1974) it can be seen that a ewe must carry an extra 0.26 of her weight during pregnancy.

The figures provide a base from which to calculate the nutrient requirements of the ewe. The foetus is most important, as the valuable end product, other material being necessary for its survival.

5.2 Intermediary Metabolism of the Foetus

The nutrition of the foetus is difficult to measure directly by nutrient flow in the blood, because of the maternal circulation, and there is little known about the contribution from the flux of amniotic fluid through the alimentary tract. Most workers have measured nutrient retention by differences between concentrations in the blood of the umbilical artery and vein. The 40-50 g crude protein and 1 MJ of energy in the amniotic fluids (Rattray et al, 1974) are unlikely to make a large contribution.

Glucose is the major energy source of the foetus, together with lactate, amino acids and acetate (Prior and Christenson, 1976; Battaglia and Meschia, 1981). As pregnancy advances the demand for glucose increases and, where dietary substrates fail to meet its body tissue reserves

Table 5.2 Weights and constituents of products of conception

Reference	Material	Days gestation	Fresh wt g	Dry wt g	Ash g	Fat g	Crude Protein g	Energy MJ
Langlands & Sutherland (1968)	Gravid uteri of Merinos with singles (excluding fluids)	145	6109	1165.2	181.6	127.0	777.5	24.02
Robinson, McDonald, Fraser & Crofts (1977)	Finn x Foetuses (2)	135-145	8930	1786.0	309.0	195.6	1268.0	39.65
McDonald, Robinson, Fraser & Smart (1979) compn.	Placentae	"	1090	142.8	12.3	14.3	117.7	3.44
Robinson, McDonald, Fraser & Gordon (1980) energy	Foetal Fluids	"	2860	77.2	22.0	0	39.8	1.09
	Uterus	"	1340	222.4	13.0	31.1	184.9	5.44
	Total (twins)	"	14220	2228.5	356.3	241.0	1610.4	49.62
Rattray, Garrett, East and Hinman (1974)	Twins							
	Foetuses	141	10290	1883.1	309.0	216.1	1286.3	40.04
	Fluids		3210	95.7	30.5	1.3	54.2	1.37
	Membranes (inc. cots)		1180	167.6	13.0	14.2	140.1	3.80
	Uterus		1130	173.6	11.0	9.9	154.0	3.97
	Gravid uterus		15800	2320	363.5	241.5	1634.6	49.18
	Mammary gland mean of H and L nutrition	140	1960	717.9	18.2	348.9	338.1	21.6
	Predicted for Gravid uterus and mammary for twins	140	18050	2958	383	618	1957	73.97

are mobilised and glucose is produced by gluconeogenesis (Steel and Leng, 1973a).

Mayes (1975) included propionate as a substrate for gluconeogenesis in ruminants, but the fact that its contribution varied from 0.19 to 0.62 made Steel and Leng (1973b) conclude that other substrates were of greater importance, particularly in poorly fed sheep.

Glycerol is also a glucogenic substance, which is continuously produced by adipose tissue. When carbohydrate is low it may be used to produce glucose in the liver or kidney. This is carried out by what is basically a reversal of glycolysis, but where energy barriers exist specific enzymes and pathways allow the reversal to take place (Mayes, 1975).

In addition to providing material for protein synthesis, some amino acids form a part of the energy economy of the foetus owing to their glucogenic nature (Leng, 1976). Lemons, Adcock, Jones, Naughton, Meschia and Battaglia (1976) found that uptakes of valine, leucine, isoleucine, arginine, phenylalanine and tyrosine were three to five times as great as incorporation into foetal protein in sheep. The plasma levels of amino acids are also sensitive to the nutrition and corticosteroid status of the ewe. Slater and Mellor (1977) found an elevated ratio of essential to non-essential amino acids to two days starvation followed by disturbed feeding patterns. This was explained by the reduced availability of glucose precursors leading to use of non-essential amino acids for glucose synthesis. Threonine, an essential amino acid, is not an important candidate for gluconeogenesis

(Egan and McRae, 1979) and it is possible that other essential amino acids are also reserved for protein synthesis. A higher level of essential amino acids may have been the result of increased protein catabolism or reduced protein synthesis. Where a very low protein allowance of 25 g crude protein per day was fed to ewes in comparison with a very high protein allowance of 130-200 g crude protein per day, the foetal to maternal plasma concentrations of amino acids were similar or higher in "low" compared with "high" ewes, suggesting an improved efficiency of protein utilisation for foetal growth (Slater and Mellor, 1972).

Nitrogen excretion has also been suggested as a role for amino acids in the foetus. Contrary to previous assumptions that interconversion of amino acids proceeds at a slow rate in foetal life, a large part of nitrogen uptake is utilised in the formation of glutamate, urea and aspartate (Lemons et al, 1976). Since there is a net flux of glutamate out of the foetus into the placenta, it is possible that this provides a route out of the foetus for nitrogen when the activity of the urea cycle is low.

Overall the foetus seems to be active in amino acid metabolism and it is possible that there is a higher requirement for protein than merely to satisfy protein deposition in the body of the foetal lamb.

5.3 Hormonal Regulation of Nutrient Flow

The priority of nutrients described by Hammond (1952) implies that some mechanism exists within an animal which directs the tissue that will be grown at the expense of catabolism or reduction in growth of another tissue. The

level of circulating hormones, controlled by higher centres in the brain, regulates this mechanism. The hormones concerned with the foetal nutrient supply include growth hormone.

Glucose homeostasis is achieved by reciprocal levels of growth hormone and insulin, which respectively increase and decrease in adaptation to the increased carbohydrate deficit in late pregnancy (Hove and Blom, 1976). Lipolytic activity is increased and glucose consumption reduced in insulin sensitive tissue.

Growth hormone has a long term somatotrophic effect (growth stimulating) and is positively correlated with growth rate (Trenkle, 1980) as it is known to increase nitrogen retention (Struempler and Burroughs, 1959; Wallace and Bassett, 1966) and has even produced increased growth rate when administered to lambs (Wagner and Veenhuizen, 1978). Insulin is also important and has the role of increasing amino acid uptake in peripheral body tissues in the sheep (Brockman, Bergman, Joo and Manns, 1975), though this would be dependent on adequate glocuse levels. This effect may not be direct (Boorman, 1980) as levels of circulating glucose and insulin have a sparing effect on the catabolism of muscle protein for energy, hence increase muscle protein accretion by reducing breakdown rather than active synthesis. Increased levels of insulin do not appear to be anabolic and it is tentatively concluded that a certain minimal concentration of insulin is necessary for protein synthesis in the muscle (Trenkle, 1980; Trenkle and Topel, 1978). The concept is discussed in relation to postnatal growth of animals, but it is presumably the same hormones which act in the rapidly growing foetus. There may be more complex relationships between maternal and foetal

hormone levels.

Glucagon increases hepatic uptake of glucogenic amino acids and reduces net retention by the muscle, though it has no direct effect on muscle protein metabolism. (Brockman, Bergman, Joo and Manns, 1975). Levels are highest immediately after feeding and decline in starvation. Glucagon prevents hypoglycaemia from occurring after feeding when there is increased utilisation of glucose, as well as during starvation when there is decreased availability of glucose precursors (Brockman, 1978).

Adrenal glucocorticoids, like glucagon, increase hepatic uptake and conversion of amino acids to glucose and reduce amino acids available to other tissue (Reilly and Black, 1973; Reilly and Ford, 1974). Exogenous cortisol has been shown by Basset (1968) to stimulate increased nitrogen excretion, suggesting protein catabolism. In laboratory animals it is proposed that adrenal glucocorticoids decrease protein synthesis and increase protein breakdown in skeletal muscle (Rosen, Kaiser, Mayer and Milholland, 1976). Blood concentration of adrenal glucocorticoids does not change immediately after feeding, but increases with starvation when insulin is low and the hormonal balance favours degradation of muscle protein and increased uptake of amino acids by the liver, resulting in loss of skeletal muscle (Mills and Jenny, 1979).

5.4 Nutritional Experiments

Two main approaches have been made in research into nutrient requirements for pregnancy. The first is to define absolute requirements for pregnancy which implies maternal body tissue maintenance and the optimum amount of nutrients to produce lambs of optimum birth weight.

The second approach has been to find the minimum allowance for pregnancy in the ewe. The aim would be to minimise incidence of nutritional disease such as pregnancy toxaemia, and to produce a lamb of adequate birth weight to ensure perinatal survival. The allowance would be supplemented by catabolism of body reserves to meet foetal demands.

5.4i Requirements for Maintenance All calculations of requirements for pregnancy must be based on an allowance for the maintenance of the ewe. In determining the requirements of a non-growing, non-pregnant, non-lactating animal the maintenance of liveweight should indicate maintenance of body and tissue and therefore, the adequacy of the allowance.

The recommended energy allowances (Table 5.3) from various sources show a difference of 0.08 MJ/kg $W^{0.75}$ which becomes about 2 MJ for a 70 kg ewe. This consititues 20-25 per cent of the total allowance. The discrepancies may have arisen because of variation in estimates of requirements for activity, for variations in herbage quality if measured in grazing sheep and from method of estimation, as discussed by Langlands, Corbett, McDonald and Reid (1963). ARC (1980) determines the maintenance requirement factorially from fasting and heat production plus work divided by the efficiency of utilisation of metabolisable energy for maintenance (K_m).

The recommended allowances for protein (Table 5.3) are at variance with one another. Comparisons are not possible because different units have been quoted. Where common units have been used, estimates vary by up to 100% (National Research Council, 1975; Lowman, 1970). Errors may have been introduced in converting units quoted in the original work

Table 5.3 Maintenance requirements of mature adults

Source	Conditions and Breed	Energy ME	Protein
Langlands, Corbett, McDonald & Pullar (1963a)	Housed Mixed breeds	0.32-0.34 MJ/ kg $W^{0.75}$	
Langlands et al (1963b)	Grazing Mixed breeds	0.40 MJ/kg $W^{0.75}$	
Agricultural Research Council (1965)	Lowland	0.32 MJ/kg$W^{0.75}$	1.28 g avail protein/kg $W^{0.75}$
Robinson & Forbes (1966)			0.86 g DCP/ kg $W^{0.75}$
Lowman (1970)	18 months Clun Forest		2.30 g CP/kg $W^{0.75}$
	Mature Clun Forest		2.15 g CP/kg $W^{0.75}$
National Research Council (1975)	Unspecified	0.41 MJ/kg$W^{0.75}$	4.42 g CP
MAFF, DAFS, DANI (1977)	Outdoors	0.36-0.37 MJ/ kg $W^{0.75}$	
	Indoors	0.32 MJ/kg$W^{0.75}$	

to those quoted in the table, but these would be small in comparison with variation caused by other factors. The estimates have been produced from balance trials (Robinson and Forbes, 1966; Lowman, 1970) and the factorial approach (Agricultural Research Council, 1965) but recently a new approach for determining protein requirements has been proposed (Agricultural Research Council, 1980). The microbial population of the rumen uses nitrogen, which the host ruminant consumes, to grow their own bodies. These bodies form microbial protein which the ruminant digests to peptides and amino acids and absorbs in the lower part of the alimentary tract along with dietary protein which is not degraded in the rumen. The Agricultural Research Council (1980) bases its recommendations on this dichotomous approach, considering the production of microbial protein in relation to energy input, the tissue protein requirements of the host animal and the supply of undegraded dietary protein. Although apparently complicated, it is a more logical approach in terms of the ruminant and explains different animal responses to different protein sources by differences in extent of degradability.

5.4ii Requirements for Pregnancy:Slaughter Trials Slaughter trial results have already been discussed in Chapter 1 and in the first section of the present chapter, but nutritional aspects will be discussed here.

The principle of the slaughter trial is that an initial group of animals, representative of a larger number is slaughtered to give an estimate of composition at the start. The remaining animals are exposed to experimental treatments and are slaughtered in one group at the end of treatment or in

a series of groups throughout the experiment, giving changes as treatment proceeds. Sometimes in pregnancy slaughter trials, non-pregnant animals exposed to the same treatment are slaughtered for comparison.

Care must be taken in interpreting slaughter trials using pregnant animals. Nutrient accretion of the foetus and adnexa should not be considered in isolation from energy and protein changes in the maternal body. Robinson,McDonald,McHattie & Pennie (1978) have shown that energy losses in the body occur which are accompanied by increased water retention resulting in maintenance of body weight. In examining nutrient intake in relation to nutrient accretion in the products of conception, changes in maternal body composition must also be taken into account.

The dry matter, protein and energy contents of foetuses and adnexa from various slaughter trials are given in Tables 5.4 and 5.5. The data for foetuses are fairly consistent, but those for adnexa vary much more because different constituents have been included in the calculation. Perhaps the most realistic approach is that of Heaney and Lodge (1975) where the estimate includes conceptus and increase in pregnancy associated tissue. To estimate the order of total nutrients in the products of conception for twins the figures of Robinson et al (1977) and Rattray et al (1974) agree at around 40 MJ of energy and 1275 g protein. Rattray et al (1974) and Heaney and Lodge (1975) have similar protein figures for single lambs, therefore it seems appropriate to use Rattray's figure of 686 g protein for the adnexa of twins since it is the only one that includes the mammary gland. The most complete value for energy of adnexa is 31 MJ

Table 5.4 Dry matter, protein and energy content of the foetus at term

Source	Breed	Days gestation	Weight kg	Dry matter g	Protein g	Energy MJ	No Lambs
Langlands & Sutherland (1968)	Merino	145	4.443	949.9	612.5	19.0	1
Sykes & Field (1972)	Scottish Blackface	Term	3.140	964.8	535.9	15.0	1
Rattray, Garrett, East & Hinman (1974)	Targhee	141	5.700	1043.1	712.5	22.2	1
			10.290	1883.1	1286.25	40.0	2
Heaney & Lodge (1975)	Rambouillet x Columbia type	140	5.094	-	892.0		1
Robinson, McDonald, Fraser & Crofts (1977) and McDonald, Robinson, Fraser & Smart (1979)	Finnish Landrace x Dorset Horn	144	8.93	1786	1268	39.65	2

Table 5.5 Weight, dry matter, protein and energy of the remaining products of conception

Source	Breed	Days gestation	Weight kg	Dry matter g	Protein g	Energy MJ	No lambs
Langlands & Sutherland [1] (1968)	Merino	145	1.755	213.5	146.9	4.573	1
Sykes & Field (1972)[2]	Scottish Blackface	Term				2.51	1
Rattray, Garrett, East[3] & Hinman (1974)	Targhee	140	4.69	769.9	458.9	20.777	1
		141	7.48	1148.4	686.4	30.710	2
Heaney & Lodge (1975)[2]	Rambouillet x Columbia type	140	4.576		481	30.96[6]	1
Robinson et al (1977) and[4] McDonald et al (1979)	Finnish Landrace x Dorset Horn	144	5.290	442.5	342.4	9.97	2
Rattray, Trigg & Ulrich[5] (1979)	Coopworth	135				31.3	2

1 Uterus and membranes
2 Uterine membranes
3 Uterus, membranes, fluids, mammary gland
4 Uterus, placentae and fluids
5 Conceptus energy - foetus, fluids and membranes
6 Foetus, placenta, fluids and gain in uterus and mammary above non-pregnant.

(Rattray et al. 1974) giving a total of 1960 g protein and 70 MJ in the products of conception of twins.

Estimates of the efficiency of utilisation vary from 0.133 (Sykes and Field, 1972c) to 0.24 (Heaney and Lodge, 1975) for energy utilisation. The wide variation may be due to different methods of calculation and the period over which efficiency was measured, that is 112 days for the former and 35 days for the latter. Robinson et al (1980) showed that efficiency varied in relation to dietary energy level from 0.118 to 0.163 and for ewes carrying twin lambs and receiving 14.40 and 11.24 MJ ME/day. respectively.

The only estimate for the efficiency of protein utilisation found was 0.25 (Sykes and Field, 1972c). It is likely that similar divergence would have been found if Heaney and Lodge (1975) had produced a figure for protein utilisation efficiency.

The estimated dietary energy required for products of conception is between 292 and 526 MJ ME and the requirement for protein is 7840 g over the period of gestation. This should incorporate the additional protein taken up by the placenta and catabolised in the foetus for energy, as discussed in the penultimate section. It also should be borne in mind that the foetus may have a special requirement for energy in the form of protein (see Section 5.2 of this chapter).

Another point not considered is mobilisation of maternal energy reserves. If body reserves were contributing to the energy balance of the foetus and this was not included in the efficiency calculation, then calculated efficiency would be greater than actual efficiency. This was not the case in Heaney and Lodge's (1975) calculation as they were comparing pregnant with non-pregnant ewes and were feeding ad libitum which may have resulted in the ewes being in

positive energy balance.

5.4iii Requirements for pregnancy: nitrogen balance trials

Nitrogen balance trials involve the recording of nitrogen intake in feed and nitrogen output in urine and faeces, which may be collected when the animal is held in a metabolism crate over a number of days. Nitrogen retention can be calculated by subtracting nitrogen output from nitrogen intake. In pregnancy this may be expected to relate to the growth of the foetus. A response in terms of an increase in nitrogen retention to an increased feed level or nitrogen concentration in the diet might be expected to give a lamb or lambs of higher birth weight. Likewise a plateau in retention, in response to increasing increments of feed or nitrogen may be taken to indicate that the requirement has been met.

Pregnancy nutrition studies have frequently included nitrogen balance experiments to illustrate the state of nitrogen metabolism mediating the response in ewe weight change and lamb birth weight to different feed or protein levels. There is quite a variation in interpretation of results.

Table 5.6 shows data from a wide range of sources reduced to common units of metabolisable energy (MJ ME), digestible crude protein (g DCP) and nitrogen (g N) per kilogram metabolic liveweight ($W^{0.75}$). Many workers (Klosterman et al, 1951; Forbes and Robinson, 1967; Lowman, 1970; McClelland and Forbes, 1971) found no response in lamb birth weight to increasing protein level and Robinson and Forbes (1968) recognised that birth weight was only reduced at verylow protein intakes of about 0.85 g DCP/kg $W^{0.75}$. As a result it has often been concluded that the lowest level

Table 5.6 Nitrogen Balance Trials

Source	Breed	No ewes	Wt kg	Energy intake MJME/kgW$^{0.75}$	Protein intake gDCP/kgW$^{0.75}$	N retention g/kgW$^{0.75}$	N requirement N = $\frac{DCP}{6.25}$ g/kgW$^{0.75}$	Lamb bwt S T	Ewe wt gain kg
Graham (1964c)	Merino	10	32	0.42	3.48	0.193		3.407	+ 4.5
				0.59	5.11	0.268		4.301	+10.5
Forbes & Robinson (1967)	BLxSBF	43	79	0.38	3.17	0.219		4.65	+ 8.76
			81	0.39	3.15	0.313		4.91	+11.13
			81	0.33	1.36	0.050		4.63	+ 5.95
			84	0.33	1.79	0.121		4.20	+ 6.68
Lowman (1970)	Clun Forest	53	69			64-88d 99-122d			
				0.37	1.97	0.115 0.190		3.74	
				0.40	2.09	0.117 0.197		3.56	
				0.39	2.33	0.149 0.225		3.62	
				0.39	2.54	0.128 inc 0.255		3.37	
				0.30	2.35	0.067 0.227		3.83	
				0.41	2.58	0.143 0.261		3.72	
				0.45	1.80	0.147 0.082 0.230		3.18	
						E M L	0.312gdigN/kgW$^{0.73}$		
	Clun Forest	61	63	0.34	1.00	-0.023 0.035 0.049		3.43	5.43
				0.34	1.26	-0.021 0.097 -0.003		3.70	7.45
				0.35	1.91	0.041 0.139 0.007		3.82	11.25
				0.36	2.80	0.051 0.200 0.088		3.82	11.41
				0.31	2.07	0.047 0.124 0.019		3.62	6.36
				0.33	1.49	0.010 0.107 0.018		3.78	7.36
				0.40	1.66	0.010 0.123 0.033		3.67	12.98
						Changes throughout pregnancy			
							0.108-0.299app. digN/kgW$^{0.75}$		
						15-16wk 19-20wks			
McClelland & Forbes (1971)	Scottish Blackface	75	51.5	0.35	1.97	0.053 0.062		4.2	
				0.35	3.03	0.099 0.113		4.3	
				0.35	4.27	0.117 0.127		4.2	
							0.315gdigN/kg$^{0.75}$		
Guada, Robinson & Fraser (1976)	Finn x Dorset	12	75	113-120d 0.48	3.71	0.22			
				No restr. 0.47	3.71	0.24			
				120-130d 0.25	1.92	-0.04		5.6	
				Restr. 0.25	1.87	-0.09		3.1	
Christenson & Prior (1976)	Finn x Targhee ewe lambs	8	57.6	0.56	4.26	0.173			
		8		0.56	4.81	0.1			
		8		0.63	6.25	0.338			
		9			5.29	0.257			
		9			4.81	0.211			
		8		0.65	5.33	0.241			
Robinson, Fraser, Corse & Gill (1970)	Romney x SBF	3	57.8	0.49	3.17	0.161		3.96	
	Romney x Swaledale	5	52.9	0.44	3.82	0.106		3.70	
		4	53.8	0.53	3.54	0.146		4.30	
		3	54.6	0.47	4.06	0.149		3.72	
		4	55.1	0.46	3.38	0.089		3.70	
		4	53.9	0.44	4.06	0.106		3.45	

offered was adequate to meet the nitrogen requirement of the pregnant ewe. Estimates vary from 0.009 to 0.275 g app. digestible N/kg $W^{0.75}$/d (Lowman, 1970), depending on the stage of gestation to 0.535 g app. dig. N/kg $W^{0.75}$/d (Robinson, 1966 quoted by Lowman, 1970) with other estimates falling between, that is 0.36 g app. dig. N/kg $W^{0.75}$ (Klosterman et al, 1951), 0.315 g dig. N/kg $W^{0.75}$ (McClelland and Forbes 1971) and 0.16 g dig. N/kg $W^{0.75}$ (Robinson, Fraser, Corse and Gill, 1970). The wide variation arises because the lowest level in the range fed has been quoted as the requirement, while no level lower than the requirement has been identified, therefore the definition of requirement has been limited by the range of levels offered in experiments rather than a level below which birth weight of the lamb is significantly reduced.

The fact that satisfactory birth weights have been achieved despite seemingly low intakes has been attributed to the good maternal body condition (McClelland and Forbes, 1971) reserves of which can be catabolised to augment dietary supply (Forbes and Robinson, 1967). It is also possible that energy intake was insufficient to allow response in birth weight to increasing increments of protein.

Graham (1964) concluded that, since a similar loss of nitrogen was observed from pregnant and non-pregnant ewes in response to increased nitrogen intake, no protein was being catabolised to supplement foetal energy supplies.

Where energy is abundant, an increasing response in nitrogen retention will occur up to a point where maximum deposition occurs, that is, where nitrogen requirement is met. Thereafter excess nitrogen will be excreted. Where energy is limiting, a response in nitrogen retention will

occur as far as energy permits, but protein may then be catabolised to meet energy demands and nitrogen will be excreted, therefore nitrogen retention may decline while requirement for nitrogen has not been met. This may explain Lowman's (1970) observation of a decline in nitrogen retention as stage of gestation advanced, while Robinson et al (1970) observed increasing nitrogen retention in ewes offered constant and increasing patterns of protein intake with higher energy intakes.

Nitrogen retention may decrease for three reasons: firstly because requirement has been met and urinary excretion increases; secondly, because energy is limiting and protein is catabolised for energy resulting in increased excretion of nitrogen; thirdly, if energy is limiting it will also reduce the production of microbial protein.

Graham (1964) recognised the high proportion of glucogenic energy required by the gravid uterus. A proportion of 0.4 of the total metabolisable energy is provided by glucogenic substrates and, of this, 0.7 is required by the uterus. Propionate is quoted as providing 0.75 of glucogenic energy (Graham, 1964) but Steel and Leng (1973b) found that other substrates were of greater importance, which may mean amino acids.

An experiment on feed restriction in late pregnancy (Guada, Robinson and Fraser, 1976) supports this suggestion as nitrogen balance decreased with food restriction as a result of increased urea nitrogen excretion.

Generally nitrogen balance experiments are not ideal for determining nitrogen requirements in pregnancy, except where there is abundant energy. It is certainly not acceptable

as a measure of foetal growth as Forbes and Robinson (1967) and others found no correlation between retention and lamb birth weight.

Nitrogen required to maintain equilibrium should not be considered in isolation from energy. Terroine and Sorg-Malter (1920) quoted by Brody (1945) reported a relatively constant ratio of endogenous nitrogen excretion to basal energy metabolism of 0.621 g N per MJ.

The new approach to protein digestion adopted by ARC (1980), whereby microbial protein production in the rumen is considered in association with energy and protein digestion in the small intestine is considered separately, may shed light on anomalies in previous experiments.

5.4iv Requirements for pregnancy: feeding trials It has long been suggested that the last third of pregnancy for the ewe is the one reqiring most attention nutritionally (Cloete, 1939; Wallace, 1948; Robinson, 1977) as this is the period when the foetus achieved 0.75 of its growth (Chapter 1). Earlier stages, before mating, early and mid pregnancy should not be overlooked, because of their importance to ovulation rate (Coop, 1962), embryonic survival (Edey, 1976) and body condition (McClelland and Forbes, 1968) although the absolute requirements are less.

Feeding trials to assess requirements in terms of gross output, lamb numbers, birth weight and ewe weight change have been used to look at different feed sources and levels and the response to increments of energy and protein, both independently and interactively. Frequently results appear to be conflicting but examination of the underlying technique involved often reveals an explanation whereby the results

actually complement each other.

a. Feeding level

Table 5.7 shows the main results from feeding trials. Many workers have simply studied the response to increasing feeding level in terms of lamb birth weight and ewe weight change. Early workers (Wallace, 1948; Thomson and Thomson, 1948-49) found a response in birth weight to increasing nutritional plane. The latter workers found that dietary restriction resulted in poor lamb vigour and low maternal vitality after labour. Wallace (1948) reported similar observations, which is not surprising considering the extreme nature of the treatments, that is straw alone compared with medium quality hay and concentrates. Twin lambs were apparently more susceptible to poor nutrition than singles and incidence of pregnancy toxaemia was recorded. It is interesting to note that Wallace (1948) in a later experiment, found that a ration of liberal hay and restricted concentrates resulted in only slightly lighter lambs than those from ewes on a ration of liberal concentrates and restricted hay. Ferguson (1975) also emphasised the value of good quality hay in reducing concentrate requirement in late pregnancy, a concept which has important economic implications.

Gardner and Hogue (1963) observed increased birth weight of twin, but not single lambs in response to increased energy in late pregnancy. A similar improvement was noted by Lodge and Heaney (1975) in single and twin lambs.

When looking at supplementation of a forage diet such as silage with a concentrate, Sheehan and Lawlor (1972) and Rutter, Broadbent and Laird (1975) noticed improvements over feeding silage alone, but this response did not increase

Table 5.7 Feeding Trials

Reference and graph symbols	Breed	Nos	Ewe Wt	Period of expt	DM intake g/kg $W^{0.75}$/d	Energy intake MJ/kg $W^{0.75}$/d	Protein intake gDCP/kg $W^{0.75}$/d	Protein source†	Lamb bwt S	Lamb bwt T	Lamb Nos	Ewe wt * Gain g/d	Ewe wt * Net kg
Wallace(1948)	BL xCh	3	61.5	42d pp	78.75	0.91	14.38	Hay + concs.		9.909	2	+338	
□■*		4	"		38.93	0.46	5.41	Hay		7.000	2	+7.6	
		4	"		22.71	0.16	0.20	Straw		5.182	2	-156	
	BL x Ch		61.5	42d pp	88.01	0.95	12.63	Hay + oatsFM,LM		9.455	2	+437	
					24.03	0.02	3.27	"		6.091	2	-114	
					100.46	1.08	14.33	"	5.545		1	+410	
Thomson and Thomson (1948-49)	S. Ch.	81	44	76d pp		0.63				7.00	2	+ 29	
△▲						0.64			4.79		1	+ 57	
						0.22				4.55	2	-171	
						0.23			3.76		1	-142	
Robinson and Forbes (1968)	BL x SBF		68		48.60	0.55	4.18	Soyabean meal		9.22		+210	+1.3
◇◆					48.82	0.53	2.79	Maize		9.18		+210	+2.5
					47.76	0.50	1.77	Barley		7.96		+160	-3.6
					47.51	0.50	0.89	Oats		7.02		+ 80	-8.8
					44.43	0.48	4.73			8.78		+160	-0.7
					43.88	0.47	3.04			8.20		+100	-5.7
					42.10	0.40	1.82			8.14		+100	-6.2
					40.03	0.40	0.80			7.36		+ 60	-7.7
McClelland and Forbes (1968)	SBF	54	42	42d pp	34.15	0.33	4.11	Soyabean meal	3.14		1	+ 50	-4.23
x⊗					34.53	0.33	5.27	+ barley	3.32		1	+ 48	-3.14
					33.91	0.33	6.71	+ fishmeal	3.95		1	+ 38	-3.55
					43.07	0.41	3.85		3.41		1	+ 64	-4.50
					44.60	0.42	5.52		4.09		1	+100	-2.45
					44.63	0.44	6.81		3.73		1	+ 88	-2.81
					54.12	0.52	4.19		3.82		1	+118	-1.09
					56.43	0.55	5.40		3.77		1	+118	-1.59
					55.04	0.53	6.89		4.36		1	+136	-3.09
Sheehan and Lawlor (1972)	BL x SBF	80	60	56d pp	46.25		3.94	Silage	4.2	6.4			
□■					51.21		4.22	" + 12kg barley	4.7	8.0			
					48.98		3.89	" + 23kg barley	5.0	7.8			
					90		8	Dried grass pellets	4.7	8.8			
Lodge and Heaney(1975)	Rambouillet x Columbia type	80	55.6 57.3	146d pp	36.21 39.50	0.33 0.28-0.53(0.4)		Ground hay barley + soya bean meal	4.84 5.26	6.30 7.98	1.21 1.31	+0.7 + 26	-5.8 -2.7
○●			53.7		32.53	0.27			4.16	5.44	1.29	- 25	-9.7
			56.0		32.45	0.27			4.02	7.80	1.36	- 47	-14.0
						Up to mating	Early preg	Late preg					
Curll, Davidson and Freer (1975)	BL x ♈ Merino	360	53.0	146d pp			0.21	0.67	Pasture	4.92	7.80	1.08	
○■						0.19	0.44	0.88		5.30	8.60	0.95	
							0.76	1.13		5.20	8.80	1.18	
							0.26	0.66		4.53	7.42	1.33	
						0.50	0.49	0.79		5.15	8.18	1.23	
							0.72	1.03		5.51	9.06	1.20	
							0.40	0.70		4.51	7.26	1.49	
						1.06	1.02	0.98		5.45	8.62	1.53	
Rutter, Broadbent and Laird (1976)	BL x SBF NO Ch.	80	76	49d pp	30.61		2.45	Rolled barley	4.4		1.5		
+⊕					37.57		3.17	+ soyabean meal	4.6		1.7		
					39.72		3.39		5.0		1.8		
					39.99		3.42		5.3		1.3		
					45.24		3.23		4.5		1.6		
					53.82		3.80		5.0		1.9		
					47.21		3.53		4.9		1.5		
					49.12		3.70		4.6		1.8		
Shevah, Black and Land (1975)	Finn x Dorset	36	65	42d pp	69.89	0.80	7.43	Barley, soya	4.3	6.4	2.0	+50	+5
▽▼					65.52	0.75	6.81	bean meal,	3.0	7.0	2.1	+50	+6
					54.60	0.64	5.90	Groundnut meal	3.0	6.6	1.8	+43	+8
					83.44	0.75	8.39		4.6	7.6	2.2	+57	0
					46.30	0.41	4.85		4.2	6.8	2.2	0	-4
Christensen and Prior (1976)	Finn x	404	57.6	46d pp	52.73	0.56		Corn and soya	4.0		1.9	+324	
✿✱			55.9		66.72	0.71		bean meal	4.1		1.9	+407	
			58.1		80.22	0.87			4.1		1.9	+416	
Prior and Christensen (1976)	Finn x	36	59.4	65d pp	31.88	0.42		Alfalfa hay	3.53	6.95	2.17		
◇◆	Targhee		59.3		54.05	0.72		soyabean meal	4.03	7.81	2.27		
	Finn x		59.5		69.88	0.93		ground yellow corn	4.97	9.17	2.00		
Sheehan, Lawlor and Bath (1975)	BL x SBF	60	68	56d pp	32.14	0.33		Dried grass,	8.6	8.6	2	+73	-6
□■					48.18	0.47	Increas	barley and soya		9.8	2	+182	-3.4
					64.27	0.60		bean meal		9.6	2	+225	-11.4
			61		27.90	0.30				8.0	2	+23	-10.2
					46.90	0.45	Increase			9.2	2	+205	-3.7
					57.54	0.55				8.8	2	+229	-0.8

$kgW^{0.75}$ - weight at mating; Net ewe wt* - mating to post partum; Gain g/d during period of experiment
Outline symbols - single lambs; Half shaded - mean of both lambs; Solid symbols - twin lambs - average wt.
* figures used for graph; † Main constituents.
Energy calculated from kg DOM x 15.19 = MJ ME

beyond a total of 12 kg barley over the last eight weeks of pregnancy (Sheehan et al, 1972) when the barley was substituted for silage to such an extent that total nutrient intake decreased.

Generally, increasing feed level produced a response in birth weight and increased ewe weight gain or reduced weight loss. The response was variable and effects of protein and energy were confounded (Robinson and Forbes, 1968).

b. Energy

Blaxter (1957) emphasised the importance of energy to pregnant animals, attributing to it variations in lamb birth weight, incidence of pregnancy toxaemia and citing it as the first limiting nutrient.

Figure 5.1 illustrates results from a variety of sources where figures have been converted to the same units. Reference to the table will identify sources of information, as each symbol represents a source, solid or ringed symbols are the mean weight of twins and hollow symbols represent the weight of single lambs. It can be seen that, while there is a general trend for birth weight to increase with energy intake per unit of metabolic liveweight, much of the variation in lamb birth weight is not accounted for by energy.

Ewe body weight gain in late pregnancy bears a steep relationship to energy intake (Figure 5.2). The increase in weight would be caused mostly by foetal and uterine tissues, but it does not necessarily relate to lamb birth weight (Christenson and Prior, 1976). A higher level of energy will spare maternal reserves and prevent the ewe utilising body tissue for maintenance and foetal growth. Indeed some weight gain is necessary to prevent net loss of ewe body weight over

Figure 5.1 Effect of energy intake on lamb birth weight

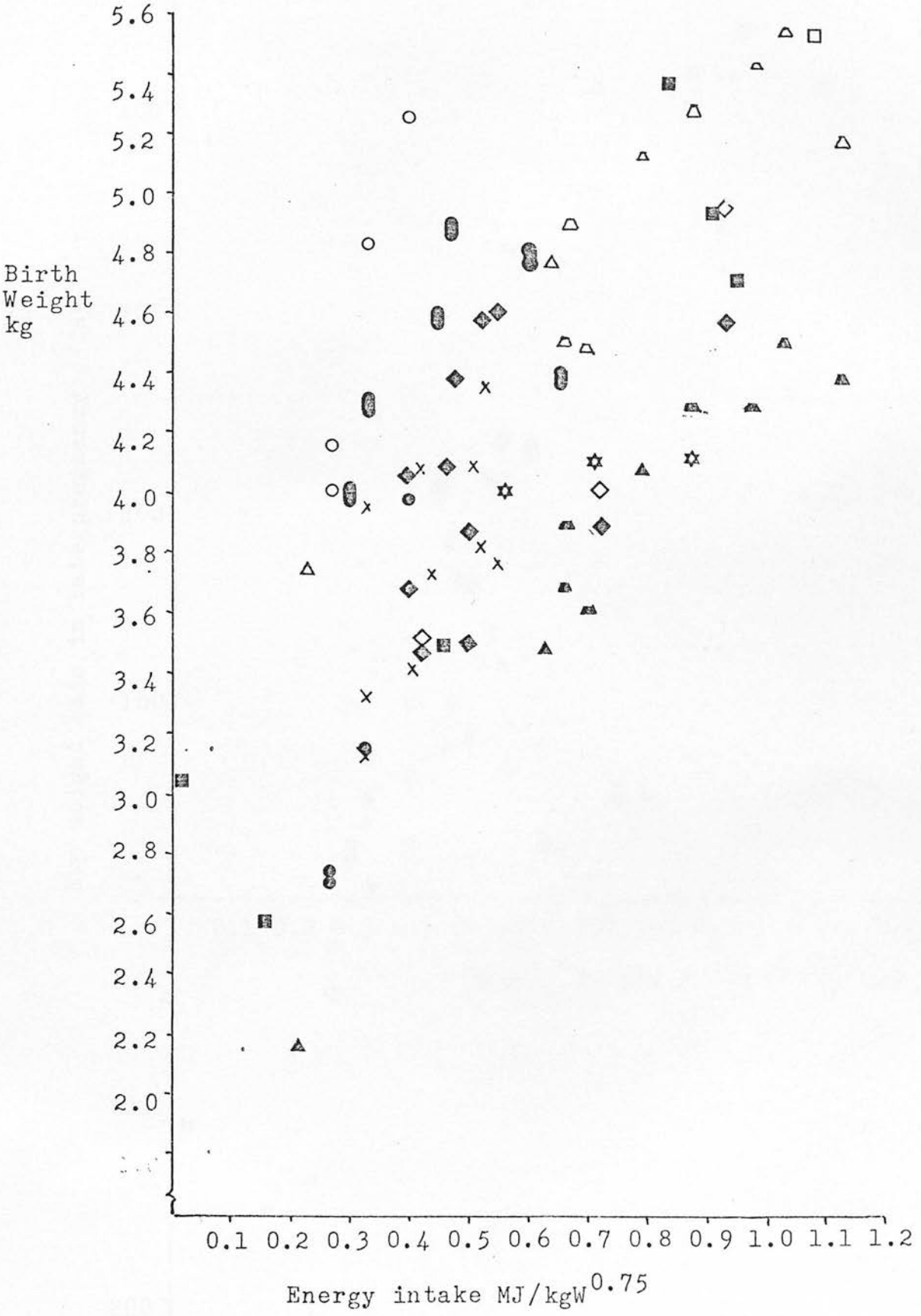
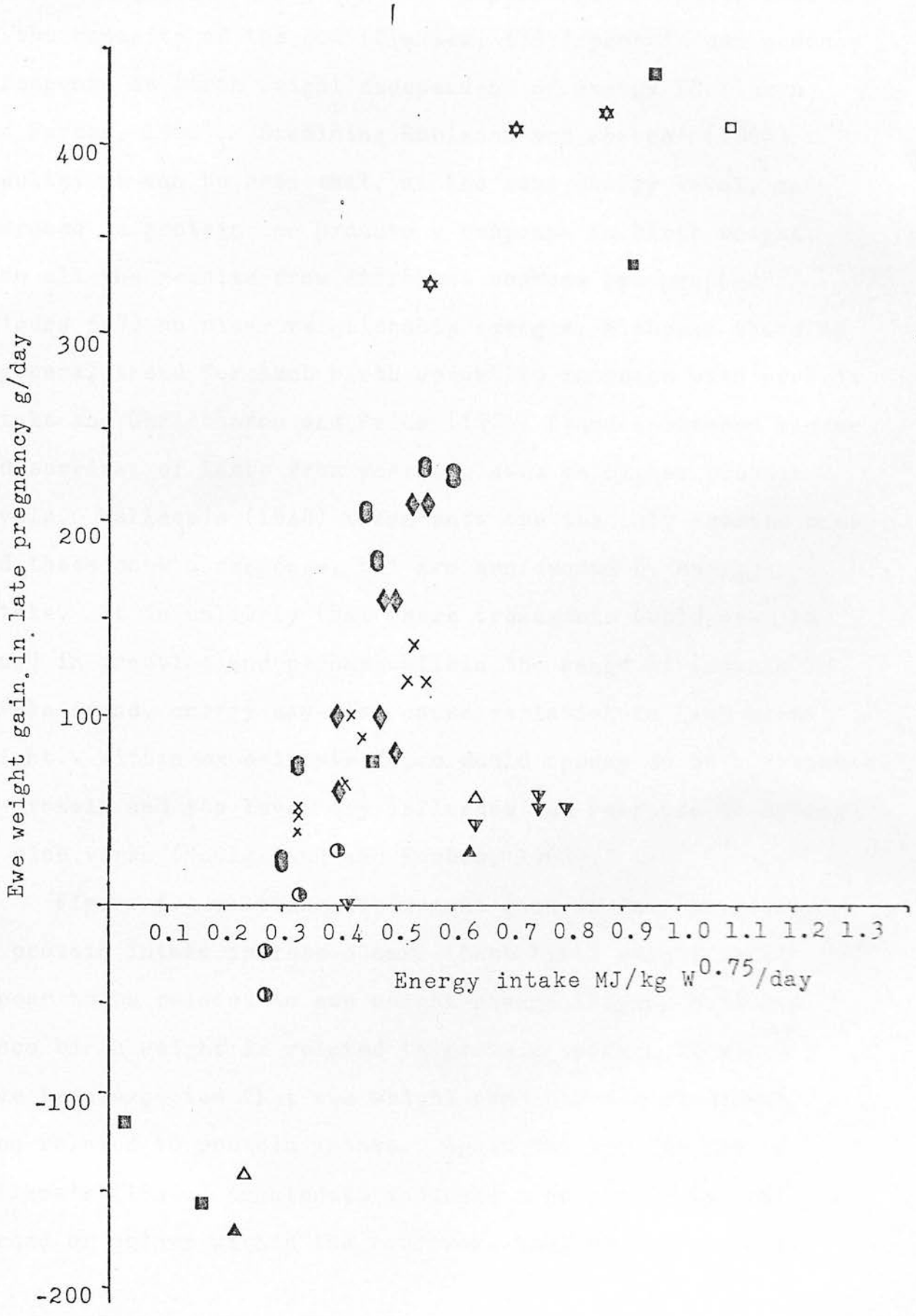


Figure 5.2 Effect of energy intake on ewe weight change in late pregnancy



the mating to prepartum period.

c. Protein

Despite the importance of energy with its physical limitation of the environment and physiological limitations of the capacity of the gut (Blaxter, 1957) protein can produce a response in birth weight independent of energy (Robinson and Forbes, 1968). Examining Robinson and Forbes' (1968) results, it can be seen that, at the same energy level, an increase in protein can produce a response in birth weight. When all the results from different sources are graphed (Figure 5.3) no clear relationship emerges, although there is a general trend for lamb birth weight to increase with protein intake and Christenson and Prior (1976) found increased vigour and survival of lambs from yearling ewes on higher protein levels. Wallace's (1948) treatments are the only extreme ones and these show a response, but are confounded by energy intake. It is unlikely that these treatments would ever be found in practice and perhaps within the range of protein levels found, energy may also cause variation in lamb birth weight. Within experiments there would appear to be a response to protein and its level may influence the response to energy or vice versa (McClelland and Forbes, 1968).

Figure 5.4 relating ewe weight gain in late pregnancy to protein intake is less clear. Lamb birth weight would appear to be related to ewe weight change (Figure 5.5) and since birth weight is related to protein intake, it would have been expected that ewe weight change would also have been related to protein intake. Again the extremities of Wallace's (1948a) treatments indicate a relationship, but the spread of points within the narrower range of experiments

Figure 5.3 Relationship between maternal protein intake and lamb birth weight

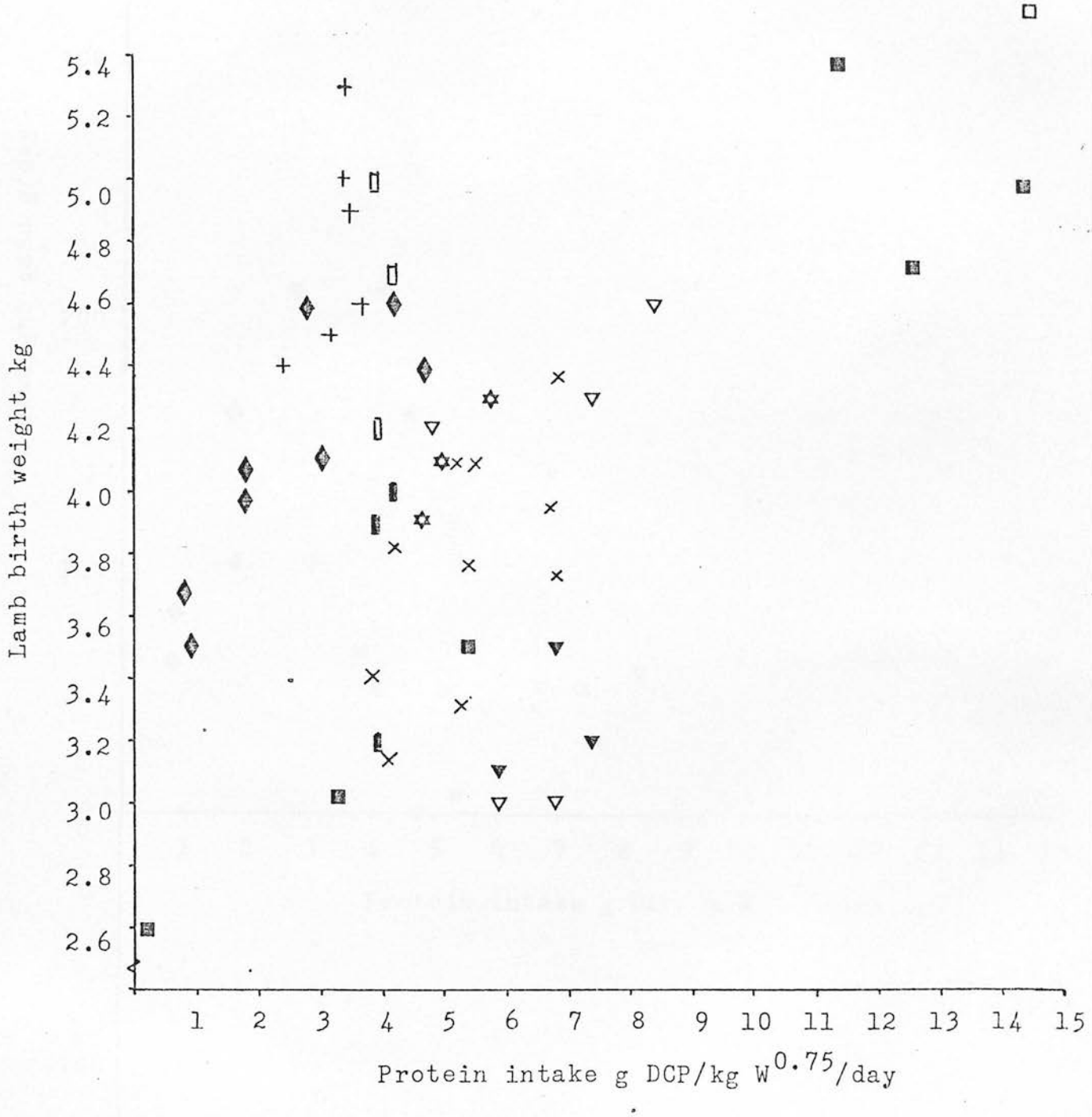


Figure 5.4 Relationship between maternal protein intake and liveweight gain in late pregnancy

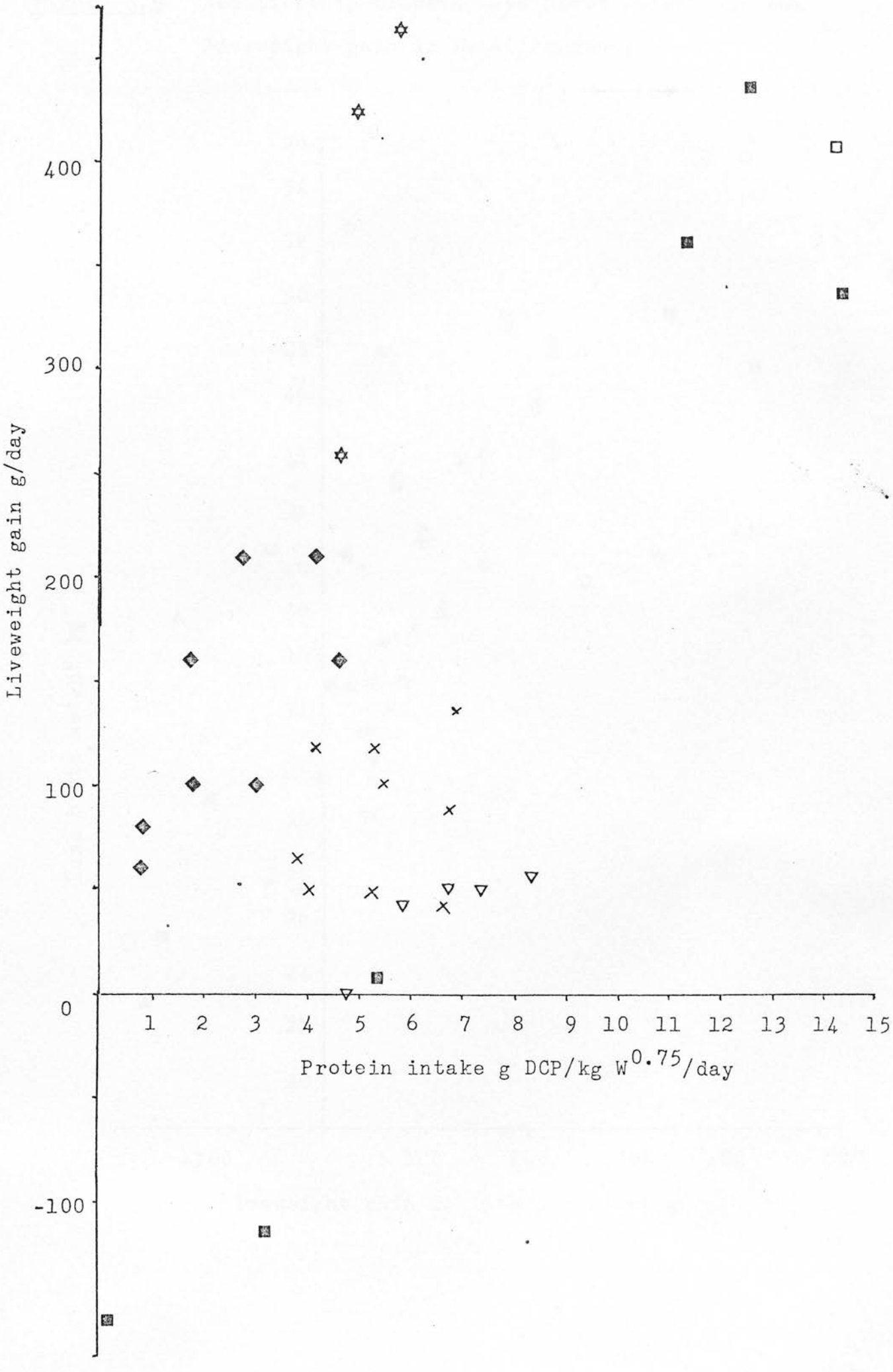
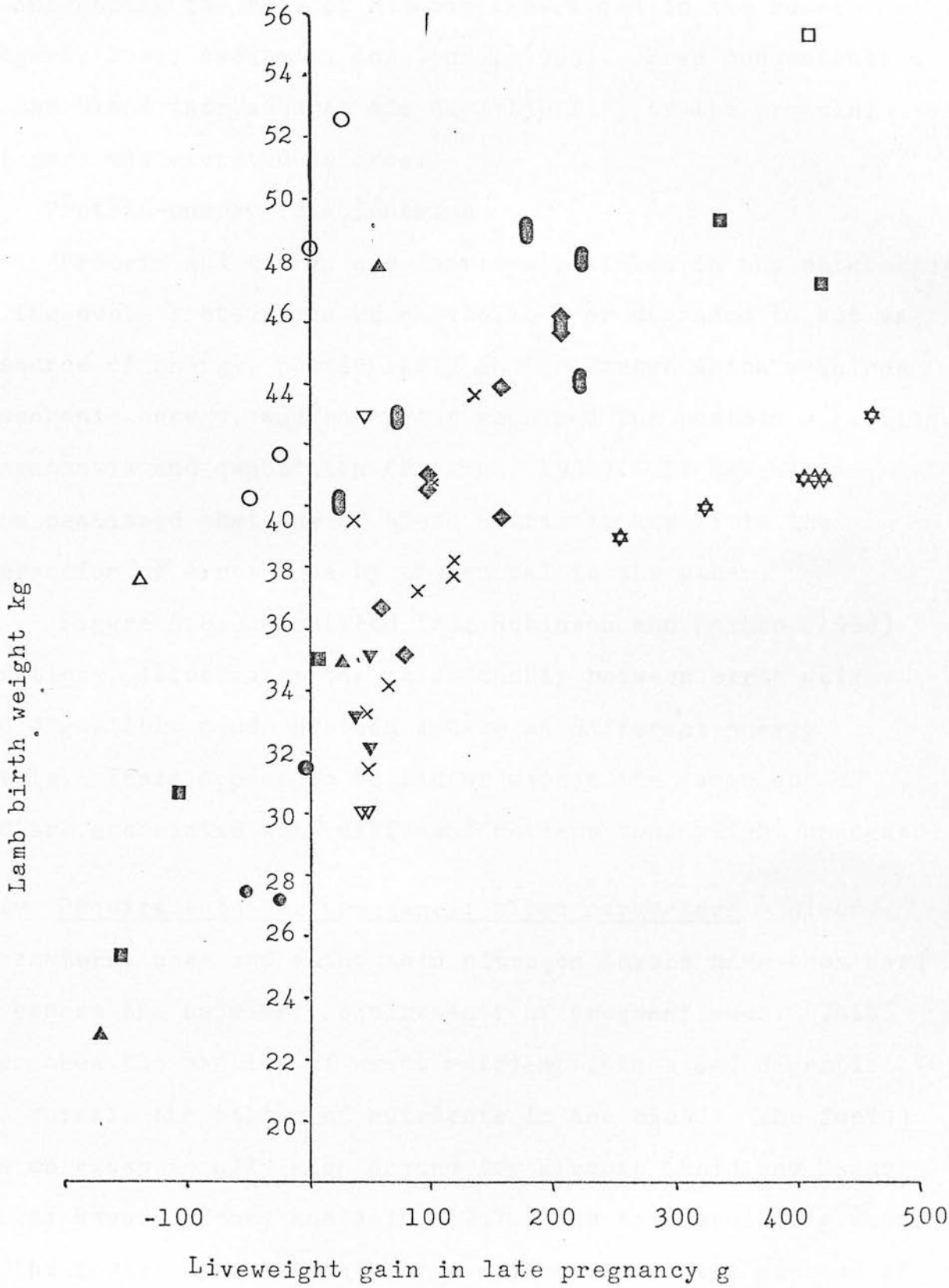


Figure 5.5 Relationship between lamb birth weight and ewe liveweight gain in late pregnancy



indicate that other factors are involved, if not totally responsible. Other constituents in the ration can influence protein utilisation, such as starch, which decreases utilisation by increasing the rate of ammonia liberation in the rumen (Tagari, Dror, Ascarelli and Bondi, 1964). Urea concentration in the blood increased as did digestibility of the protein, but more was excreted as urea.

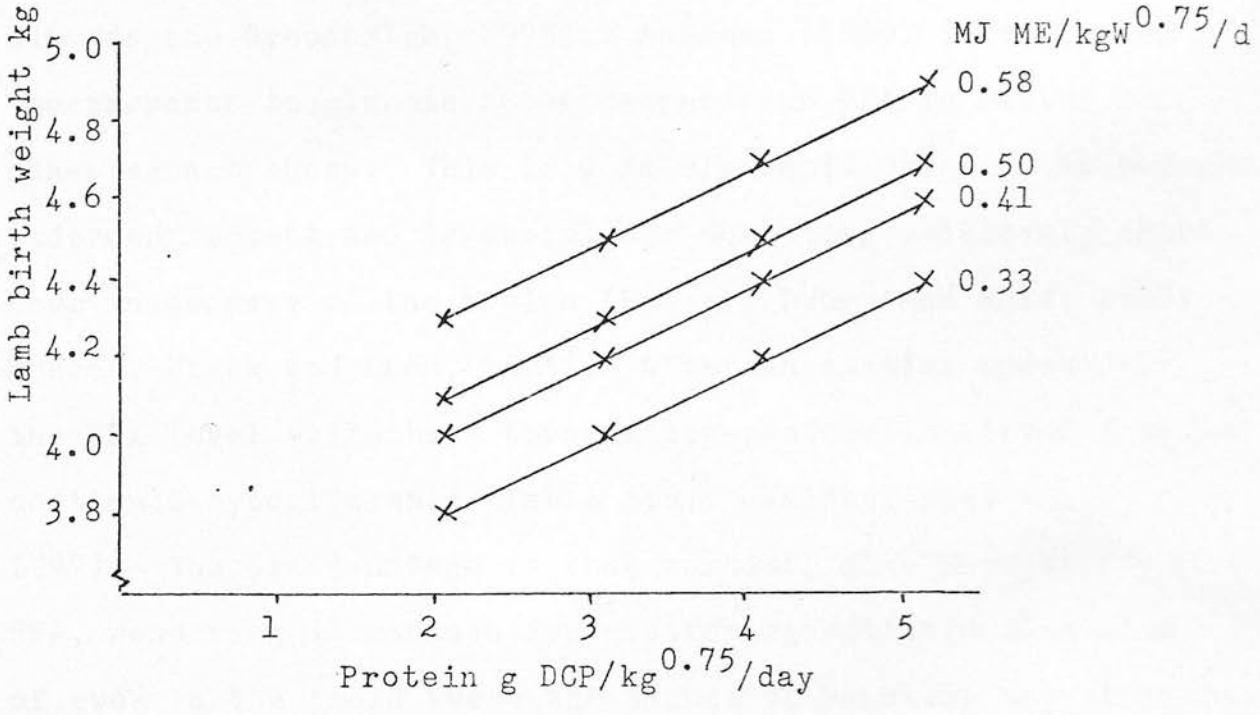
d. Protein-energy relationships

Protein and energy are inevitably linked in the metabolism of the ewe. Protein can be catabolised or degraded to act as a source of energy, particularly in the foetus which requires glucogenic energy, and energy is required for protein digestion, resynthesis and deposition (Boorman, 1980). It has already been mentioned that one of these nutrients may limit the expression of a response by the animal to the other.

Figure 5.6, calculated from Robinson and Forbes (1968) equations, illustrates the relationship between birth weight and digestible crude protein intake at different energy levels. These appear to be linear within the range quoted and are associated with different net ewe body weight changes.

5.4v Requirements for pregnancy: blood parameters Blood parameters, urea and amino acid nitrogen levels have been used to assess the nutrient requirements of pregnant ewes. This overcomes the problem of exact nutrient intake and digestibility and reveals the status of nutrients in the blood. The foetus has an exceptionally high demand for glucose (Reid and Hinks, 1962a; Russel, Doney and Reid, 1967a) and the level of glucose in the foetal circulation can be maintained at the expense of maternal supply (Russel et al, 1967a).

Figure 5.6 The effect of protein intake on lamb birth weight at different energy intakes.



Source: Robinson and Forbes (1968)

At first sight the level of maternal glucose would appear to be a good measure of nutritional adequacy. However blood glucose can be maintained by several factors, protein may be catabolised (Reid and Hinks, 1962b) and blood glucose raised by hepatic glucogenesis; decreased insulin levels can prevent glucose uptake by maternal tissues, therefore glucose homeostasis may be preserved while the ewe is undernourished.

As blood glucose level declines below a critical level of about 25 mg/100 ml (Reid and Hinks, 1962c), free fatty acids (FFA) from mobilisation of fat in adipose tissue, increase in level as there is inadequate glucose to balance their entry into the tricarboxylic acid (TCA) cycle (McDonald, Edwards and Greenhalgh, 1975). Annison (1960) demonstrated the response to glucose by the decrease in FFA in fasted and non-pregnant sheep. This is a fairly rapid response to moderate undernourishment and is useful for detecting relatively short term inadequacy of the ration (Russel, Doney and Reid, 1967; Shevah, Black and Land, 1975). After an initial increase, the FFA level falls back towards pre-restriction level despite continued hypoglycaemia (Table 5.8; Valdez Espinosa et al. 1977). The disadvantage is that cortisol also increases FFA, rendering it useless for monitoring nutritional status of ewes in the field where the stress of handling may stimulate cortisol release. (Russel, Maxwell and Foot, 1973).

Acetyl CoA, derived from fatty acids, cannot be used in the TCA cycle without adequate oxaloacetate, derived from glucogenic substrates. It is diverted into an alternative cycle which gives incomplete oxidation to carbon dioxide and water and results in the production of the ketones, acetone, β - hydroxybutyrate and acetoacetate (McDonald, Edwards and

Table 5.8 Effect of nutrition on blood parameters

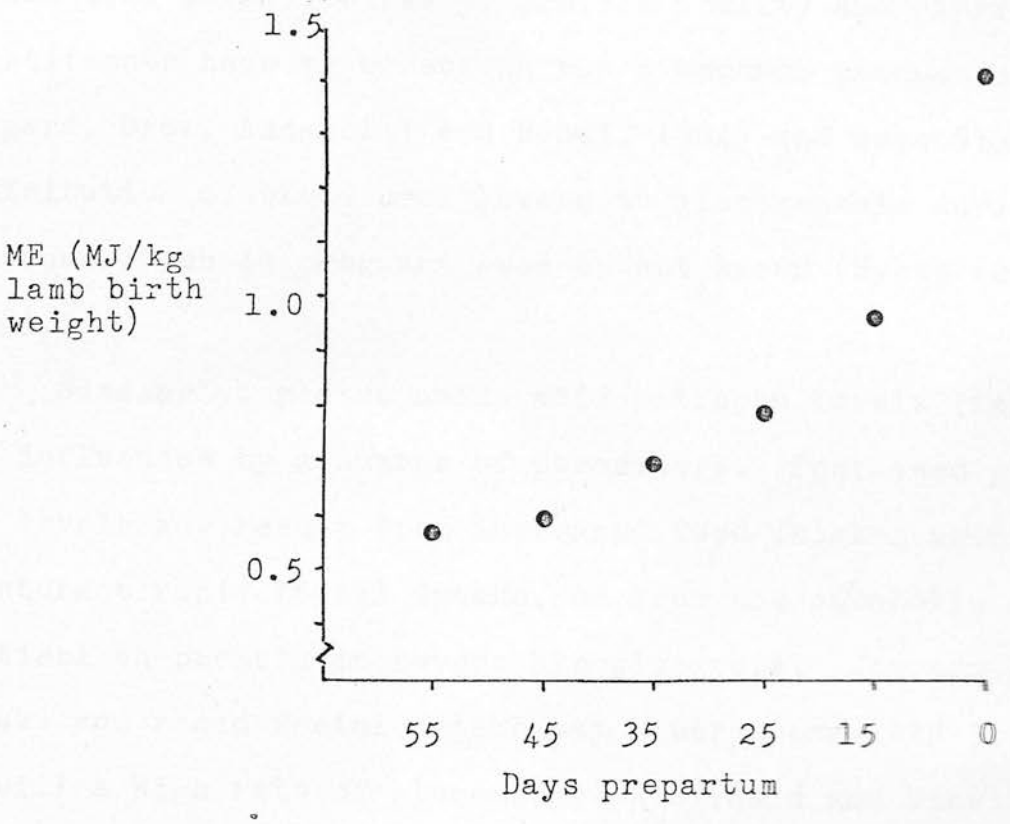
Source	Breed	Nos	Ewe wt	Treatment	Feed Intake	Glucose mg/100 ml	FFA or NEFA ueq iiv/100 ml	Ketones mg/100 ml	Urea mg/100 ml	Birthweight Singles kg	Birthweight Twins kg	Ewe weight change Gain g/d	Ewe weight change Net kg
Reid & Hinks (1962a)	Border Leicester x Merino 6-8 yrs	7	-	'constant intake'	20g/kg W/d throughout	38→33 (38→10)		1→4(1→19)		3.84	3.17	+65(+81)	-3.7(-7.0)
		7	-	'adjusted intake'	20g/kgW/d till day 50, then by 2,4 or 6g/kgW/d	~40 (37)		1-2 (1→4)		4.44	3.53	+92(+56)	-2.8(-4.9)
		7	-	'ad lib'	20g/kgW/d till day 50 then ad lib (feed:1:1 chaffed wheaten & lucerne hays, 13% CP)	42→37(41→37)		<2 (<2)		3.99	3.11	+95(+76)	-2.2(-7.8)
Reid & Hinks (1962b)	As above			as above	as above	() for ewes with twins							
						37 (21)		18	(AAN) 5-6	3.8	3.5		
						37 (35)		5	5-6	4.0	3.8		
						40+(35)		5	5-6	4.1	3.5		
Davies, Johnston & Ross (1971)	Leicester xSwale Colbred x Swale			13-21 wks	Estimated MEMJ/kgW$^{0.75}$ hay and concentrates	110d 124d 138d	Days 110 124 138	Acetone Days 110 124 138					
			66.7	E1 maint.	0.41	42 47 43	875 806 926	3.8 5.7 4.0		5.38		+71	-3.6
			72.4	E2 maint.	0.28	46 36 41	1243 1638 1154	4.8 6.6 5.7		5.90		+11	-7.4
			74.3	E1	0.41	35 36 35	1380 1120 1208	6.9 8.1 7.4			4.60	+95	-8.3
			71.8	E2	0.28	28 28 30	1893 1816 1883	16.7 25.8 7.4			3.61	-41	-12.0
			71.1	E1	0.41	31 26 29	1743 1765 1895	10.0 10.4 7.1		Triplets	3.55	+113	-12.3
			76.3	E2	0.28	17 21 26	1900 1630 1600	24.1 31.5 25.4			3.63	+96	-10.4
				E1	0.41 } non pregnant	46 49 50	260 90 380	1.1 2.0 3.1					
				E2	0.28 }	46 55 54	400 520 550	1.2 2.0 2.0					
					Energy MJME/kgW$^{0.75}$	gDCP/kgW$^{0.75}$							
Shevah, Black & Laird (1975)	Finn x Dorset	12	53	ad-lib	0.94	8.65	70	231	2.9			4.3 3.2	100 5
		12	57	100% req.	0.83	7.52	71	372	2.4			3.0 3.5	107 6
		12	51	80% req.	0.77	7.07	64	532	1.8			3.0 3.3	114 8
		24	66	100% req.	0.74	8.29	55	582	2.7			4.6 3.8	71 0
		24	65	50% req.	0.42	4.85	46	995	4.2			4.2 3.4	29 -4
Valdez Espinosa,	Finn x Dorset	9	80	days gestation	Diet: 60%hay,24%rolled barley, 11%soybeanmeal, 5% molasses + mins.								
				95-110	1.5kg feed	52	288		27				
				95-110		114-121 122-128 130-136	114-121 122-128 130-136		114-121 122-128 130-136	3.44			
				111-136 T1	1.25 0.38MJ ME/kgW$^{0.75}$	3.27gaDCP/kgW$^{0.75}$							
						54 50 49	415 500 620		28.5 27.4 23.9	3.07			
				" T2	0.95 0.31	2.74	44 41 38		25.8 25.3 25.8	2.78			
				" T3	0.65 0.20	1.70	532 675 756		28.6 29.5 27.0				
				136-146			37 27 26						
							1057 1389 1291						

Greenhalgh, 1975). Ketone levels in the blood rise and can be measured as an index of longer term, more severe under-nutrition (Russel, Doney and Reid, 1967). Davies, Johnston and Ross (1971) claimed that acetone levels were a more sensitive measure of undernourishment than FFA, but they were studying a fairly severe level (Table 5.8).

When measured in conjunction with recorded nutrient intakes of ewes in late pregnancy, relationships can be established between the parameter level, ewe body weight, energy intake and lamb birth weight. Using this method Russel et al (1967b), Robinson, Fraser and Bennet (1971) and Valdez Espinosa, Robinson and Scott (1977) have estimated that, in addition to maternal maintenance requirements of about 0.38 MJ ME/kg $W^{0.75}$, 1.5 MJ ME is required daily per kilogramme of foetus (Figure 5.7). This resulted in estimates of energy requirements for pregnancy of 19 MJ ME/ewe/day (Russel, Doney and Reid, 1976b) which was high in comparison with Langlands and Sutherland (1968), Robinson and Forbes (1967) and Robinson et al (1970) estimates of requirements for pregnancy. Langlands and Sutherland (1968) did not take into account maternal composition changes and recently it has transpired that these estimates may be more accurate than accepted levels at that time, since the average of about 13 MJ ME/day throughout late pregnancy (MAFF, 1975) has resulted in energy losses disproportionately higher than body weight changes, due to alteration in maternal composition (Robinson, Smart and Pennie, 1978).

While these high levels would allow the ewe to meet absolute requirements of the foetus and adnexa, they need

Figure 5.7 Energy required above maternal maintenance to maintain a basal level of plasma FFA concentration in pregnant ewes.
(Adapted from Robinson, Fraser and Bennet, 1971)



not be recommended allowances. Economically, it would be desirable for the ewe to mobilise body reserves over the winter months, reduce concentrate usage and increase utilisation of conserved forage.

Although plasma urea and protein intake have been linked through rumen ammonia levels (Lewis, 1957; Sykes and Field, 1973) its use to assess adequacy of a ration is limited because several factors may account for a single plasma urea level. Firstly, protein quality and other dietary constituents have an effect on rumen ammonia production (Tagari, Dror, Ascarelli and Bondi, 1964) and secondly the contribution of blood urea levels to glucogenesis during undernutrition in pregnant ewes is not known (Sykes and Field, 1973).

Similarly, plasma amino acid nitrogen levels (AAN) are influenced by a number of parameters. Increased plasma AAN levels may result from increased feed intakes which counteract rapid foetal uptake, or from the catabolic effect of cortisol on protein in severe hypoglycaemia. Conversely low intake and rapid foetal uptake may lower plasma AAN levels, as will a high rate of gluconeogenesis (Reid and Hinks, 1962b). Recent work with goats has indicated that changing ratios of certain amino acids in the blood may provide a useful index of protein status (Fujihara and Tasaki, 1980).

In addition to use of biochemical parameters to assess nutritional status, Russel, Maxwell, Sibbald and McDonald (1977) have used β-hydroxybutyrate to maintain nutritional levels by adjusting feed allowance accordingly. Foetal energy requirements per kg of foetus declined over the last six weeks <u>prepartum</u> due to changing relative growth rate

(Figure 5.8), but absolute requirements rose. The allowances necessary to maintain the prescribed nutritional states of adequate nourishment, moderate and severe undernourishment were 0.348, 0.271 and 0.231 MJ ME/kg $W^{0.75}$/day compared with 0.344 MJ ME/kg $W^{0.75}$/day for maintenance. This was consistent with other results, for example, Langlands and Sutherland (1968) and would allow rationing at an economic level with acceptable body weight losses without significantly reducing lamb birth weight. The treatment deemed "adequate" may not satisfy absolute requirements of the ewe in late pregnancy. Although a net body weight gain was observed, composition may have changed (Robinson et al, 1978). Adequacy of this level could only be confirmed by slaughter trials.

Repeatability of blood parameters among experiments is questionable where conditions are different. While, within experiments, measurements may provide a relative assessment of treatments, general use of blood parameters may be restricted.

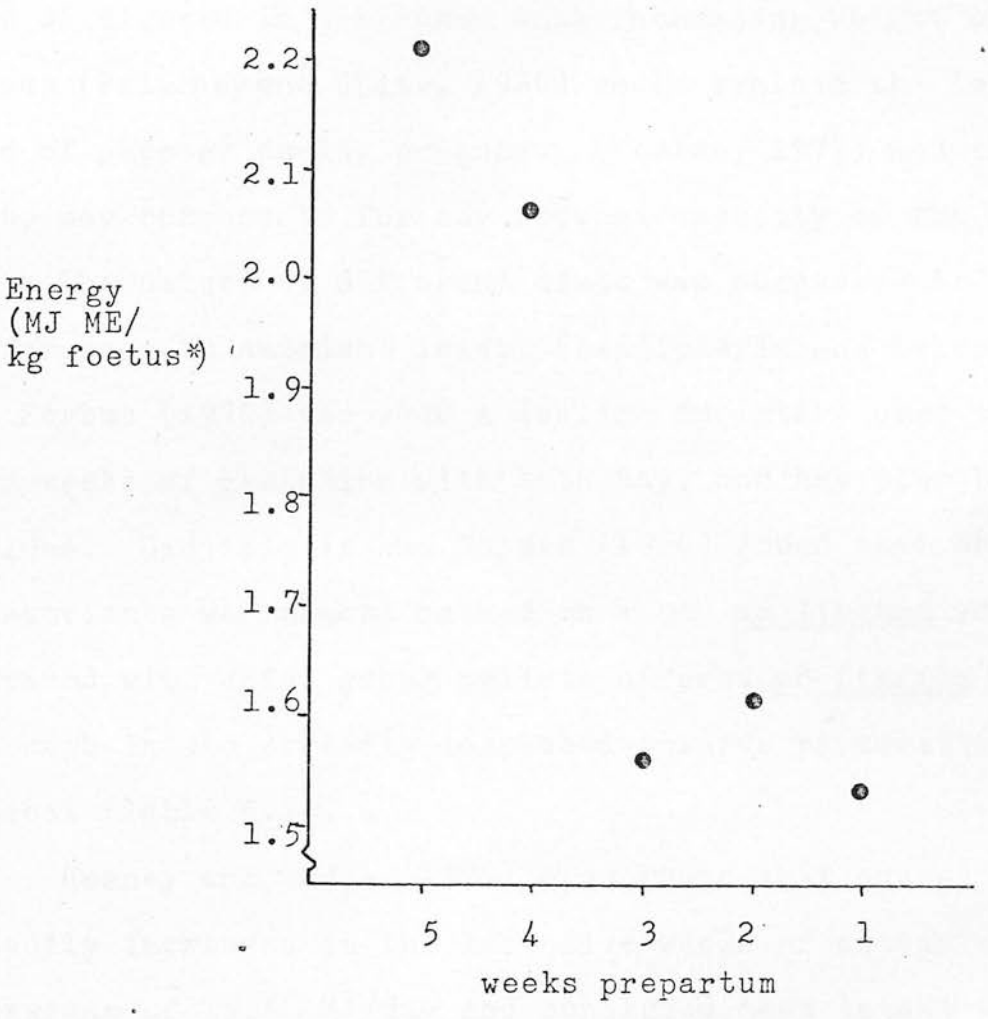
5.5 Voluntary Intake during Pregnancy

A decline in voluntary intake by the ewe in late pregnancy has frequently been observed (Gordon and Tribe, 1951; Blaxter, 1957; Forbes, 1970 and Forbes, 1977). (Figure 5.6). There has been much speculation on the cause and a number of factors are likely to be responsible.

Firstly, fatness was found by Forbes (1977) to be inversely related to intake, supported by Foot and Russel (1979) who observed a decline in intake in ewes in good condition. Non-pregnant animals which are fat also have reduced intakes as shown in cows by Bines, Suzuki and Balch (1969) and in

Figure 5.8 Estimated foetal energy requirements in late pregnancy (Source: Russel et al, 1977)

(*NB kg foetus at the time of measurement, not birth weight)



ewes by Foot and Russel (1979).

Forbes (1970) suggested that increasing uterine volume in late pregnancy reduced the rumen capacity and hence reduced intake. The reduction in intake in ewes bearing twins was the same as for ewes bearing singles, therefore it seems unlikely that this could be the sole reason. A reduced time of digesta in the rumen with increasing weight of gravid uterus (Faichney and White, 1980) would explain the increased rate of passage during pregnancy (Weston, 1979) and this, in part, may compensate for any reduced capacity of the gut.

The nature of different diets was suggested to cause differences in nutrient intake (Hadjipieris and Holmes, 1966), but Forbes (1970) recorded a decline in intake over the last five weeks of gestation with both hay, and hay plus barley rations. Hadjipieris and Holmes (1966) found that the intake of nutrients was almost halved on a hay ad libitum ration compared with dried grass pellets offered ad libitum although intake steadily increased towards parturition on both rations (Table 5.9).

Heaney and Lodge (1975) also found that energy intake steadily increased in the last five weeks of gestation up to a maximum of 15.86 MJ/day and concluded that intake need not limit the ewe's capacity to consume sufficient energy to prevent tissue catabolism in late pregnancy. Likewise Reid and Hinks (1962a) and Foot and Russel (1979) only recorded a decline in intake in twin bearing ewes in good condition.

It is apparent that under certain circumstances voluntary intake of pregnant ewes does decline in late pregnancy. The mechanism controlling this may be hormonal

Table 5.9 Voluntary dry matter and energy intake of pregnant ewes carrying different foetal loads

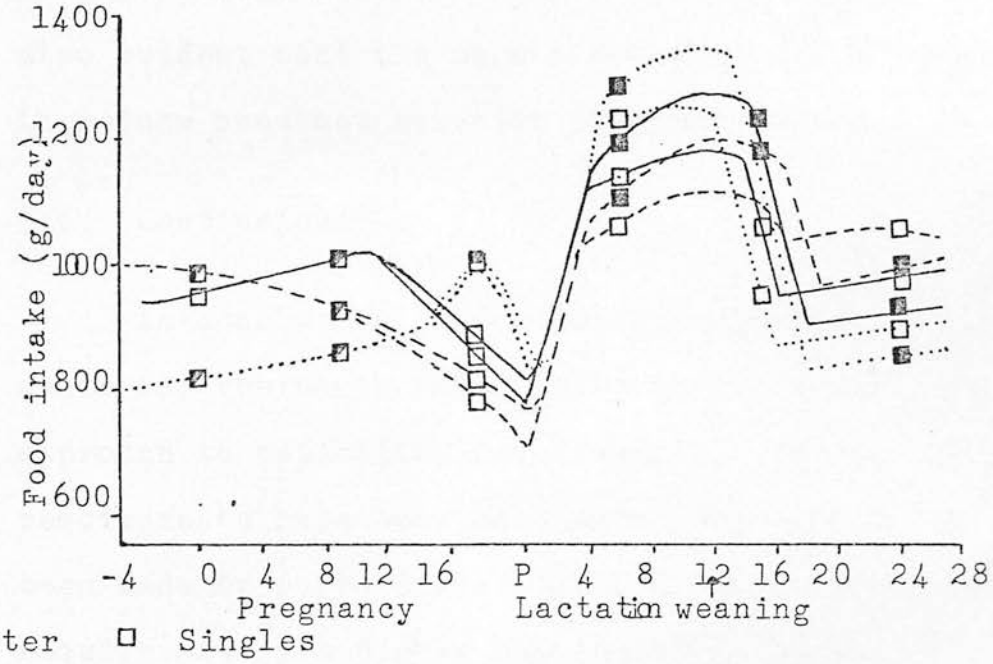
Breed	Litter Size	Feed	Ewe wt kg	Dry matter intake* g/kgW$^{0.75}$ 2 wks pp	Dry matter intake* g/kgW$^{0.75}$ 1 wk pp	ME intake+ MJ/kgW$^{0.75}$ 2 wks pp	ME intake+ MJ/kgW$^{0.75}$ 1 wk pp
Border Leicester x Cheviot	Singles	Dried grass (DG) ad lib		110.18	112.80	0.79	0.81
		1500g DG + hay ad lib		-	-	-	-
		Hay ad lib		40.25	47.50	0.31	0.37
	Twins	DG ad lib		102.31	96.19	0.74	0.69
		1500g DG + hay ad lib		107.37	111.84	0.76	0.79
		Hay ad lib		56.36	-	0.44	-
	Triplets	DG ad lib		111.92	91.81	0.81	0.66
		1500 g DG + hay ad lib		-	105.58	-	0.74

Source: Hadjipieris and Holmes (1966)

* DM g/kgW$^{0.75}$ = $\frac{\text{Digestible organic matter intake DOMI}}{\text{Dry matter \% x Dig. organic matter \%}} \times 10^4 / (\text{Ewe wt})^{0.75}$

\+ ME MJ/kg W$^{0.75}$ = $\frac{\text{DOMI x 3.64 x 4.184}}{1000} / (\text{Ewe wt})^{0.75}$

Figure 5.9 Predicted voluntary intakes of three feeds by pregnant and lactating ewes.



Litter size: □ Singles
■ Twins

DM digestibilities: 75%
——— 65%
------ 55%

Source: Forbes (1977)

in that rising oestrogen levels, known to occur in late pregnancy, have also been associated with depressed intake (Forbes, 1970), but this seems unlikely as it would have been observed in all cases. Metabolic control is another possibility which seemsmore plausible. For example, level of ketones may depress intake (Reid and Hinks, 1962), which may explain why it occurred in the fatter ewes with heavy foetal loads, but it may be difficult to distinguish between cause and effect, since decreased intake would cause a rise in blood ketones.

It is possible that more than one factor is involved in the mechanism causing depression in intake, but it is also evident that the phenomenon does not always occur therefore need not restrict nutrient supply.

5.6 Conclusions

In conclusion, the recently published nutrient requirements for ruminants (ARC, 1980) adopts a more realistic approach to estimating requirements. Energy and protein requirements have been considered together and allowance has been made for rumen degradable and undegradable protein. The requirements are higher than those given in previous publications (ARC, 1965; NRC, 1975; MAFF, 1975 and SAC, 1978). While they may not be met for a commercial flock, at least the farmer may be aware of the deficit and balance nutrients in the ration to optimise use of body reserves.

CHAPTER 6

EWE NUTRITION FOR LACTATION

6.1 The Lactation Curve

Fundamental to an examination of the nutrient requirements of the ewe for lactation is a knowledge of the pattern of lactation and the composition of ewe milk. In Wallace's (1948a) classical work the general curve is given for Border Leicester x Cheviot and Suffolk ewes over 16 and 17 weeks of lactation (Figure 6.1). The graph illustrates the characteristically steep incline, the peak two to three weeks after parturition and the gradual decline. The differences between the curves cannot be attributed exclusively to breed differences but are more likely to be due to nutritional treatment (Wallace, 1948a).

Variation in time to peak yield, amount and total milk yield are shown in Table 6.1. Nutrition, genotype, number of lambs, age of ewe and presence of disease all influence the pattern and yield (Doney, Peart, Smith and Louda, 1979). Hill ewes tend to have lower overall yields and take a longer time to reach peak.

6.2 Milk Composition

The average milk compositions, given in Table 6.2, from different sources are in reasonable agreement with each other. Variations in milk composition have been found to occur with stage of lactation, age of ewe and plane of nutrition (Barnicoat et al, 1949). The change with stage of lactation is most marked during the transition from colostrum to normal

Figure 6.1 The lactation curves for Border Leicester x Cheviot and Suffolk ewes (Wallace, 1948)

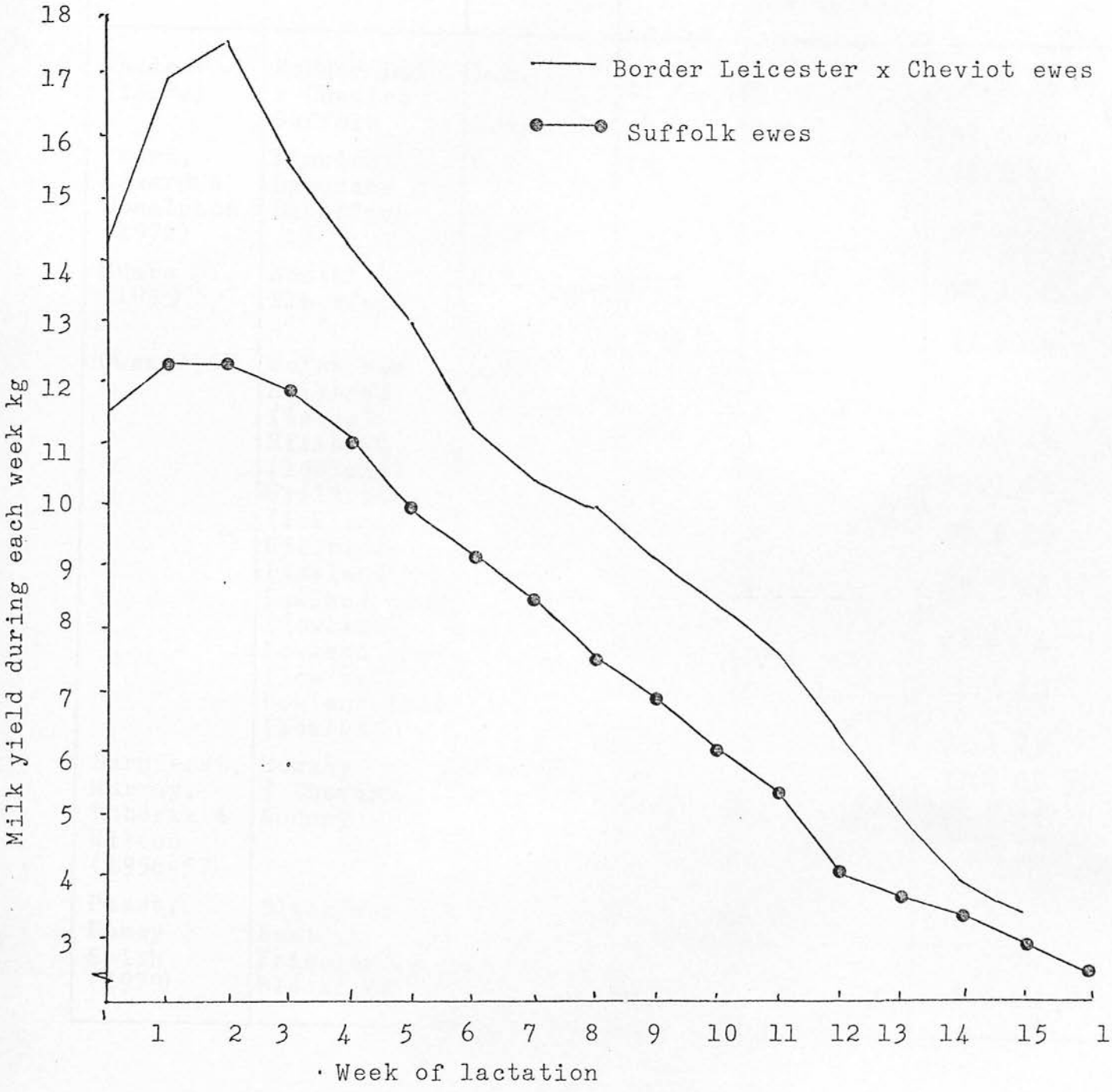


Table 6.1 Mean and peak milk yields of different breeds

Source	Breed	Technique	Peak Yield kg/week	Time of Peak Weeks from Parturition	Total/Time Yield weeks
Wallace (1948a)	Border Leic x Cheviot	L.S.	17.5	3	166.5 16
"	Suffolk	L.S.	12.3	2-3	133.6 20
Peart, Edwards & Donaldson (1972)	Finnish Landrace x Blackface	O.T.	18.1	3	178.0 12
Munro (1955)	Scottish Blackface	L.S.	15.7	4	72.3 6
	"	L.S.	8.4	5	43.6 6
Owen(1957)	Welsh Mtn Hillbred (inbye)	L.S.	7.1	2	34.4 6
	Hillbred (lowland)		8.9	2	76.3 10
	Hillbred (lowland)		10.2	3	77.9 10
	Hillbred (lowland)		11.7	4	93.7 10
	Lowland bred (lowland)		10.5	3	37.2 4
	Lowland bred (lowland)		7.8	4	71.8 10
	Lowland bred (lowland)		11.2	3	94.2 10
Barnicoat, Murray, Roberts & Wilson (1956-57)	Romney		-	-	93.7 12
	¾ Cheviot		14.9	4	136.0 12
	Romney		15.5	3	136.0 12
Peart, Doney & Smith (1979)	Blackface		19.7	6	215.0 14
	East Friesland x Blackface		23.2	3	291.6 14

L.S. lambs suckling

O.T. oxytocin technique

Table 6.2 Milk composition of different ewe breeds

Source	Breed	Week	Milk Composition					
			Total Solids	SNF	Fat	Protein	Energy	Lactose
Peart, Doney & Smith (1979)	Blackface	6	16.01	10.95	5.06		3.93	
		11	18.47	11.42	7.05		4.75	
		14	18.61	11.99	6.62		4.70	
	East Friesland xBlackface	6	16.83	11.26	5.57		4.18	
		11	16.15	11.14	5.01		3.95	
		14	16.55	11.43	5.12		4.05	
Barnicoat, Murray, Roberts & Wilson (1956-57)	Romney av.		16.30	10.80	5.50	5.50		4.40
	Romney av.		16.41	10.65	5.76	5.31		4.44
	¾ Cheviot av.		17.73	11.09	6.64	5.71		4.48
Owen(1957)	Welsh Mtn Hill bred (inbye)		17.48	11.15	6.33	5.58		4.71
	Hill and Lowland (lowland)		17.57	11.67	5.88	5.73		5.26
Barnicoat, Logan & Grant (1949)	Romney 2 years old		15.99	10.89	5.10	5.50		4.67
	6 years old		16.91	10.85	6.06	5.50		4.53
Munro (1955)	Scottish Blackface		19.76	9.84	9.35	5.05		4.48

milk secretion. Table 6.3 shows the difference in composition between the initial colostrum composition and composition after the first sucklings. (Barnicoat et al, 1949) The total solids have dropped by 25 per cent, most of which is attributable to fat and, to a lesser extent, protein. Lactose is low in colostrum and is approximately half its eventual value. In the transition to milk, total solids drops by about half again, this time mostly on account of protein and lactose rises. The compositions given by Peart et al (1979) do not show the same dramatic change, but samples were obtained on the second, third and fourth day post partum after some of the changes would have occurred.

In Romney ewes a significantly lower percentage of fat has been noted in milk from 6 year old compared with 2 year old ewes (Barnicoat et al, 1949), although other constituents remained at a similar level.

The same workers investigated the effect of plane of nutrition on milk composition and found that a low plane of nutrition primarily reduced milk yield and was accompanied by a rise in both fat and solids-not-fat, but a decrease in protein content. Gonzalez, Robinson, McHattie and Fraser (1982) noted that an improved protein content in the diet resulted in an improved protein content in the milk.

Within a milking period fat content can vary from 65.1 g/kg to 74.1 g/kg (Peart et al, 1979) or a more extreme level from 3 to 13.3% (Hernandez de Tejada, Gomez, Torres and Blas, 1975) rising from the early stages of milking to the end. This would suggest that care is required when choosing a sampling technique in that, either a sample would have to be drawn from the bulk of milk or collected at the same stage in milking each ewe in order to compare treatments.

Table 6.3 Change in composition of Romney ewes' colostrum

	Pure Colostrum	Later Colostrum	Milk
Total solids (g/kg)	411.0	311.1	159.9
Fat	181.5	110.3	51.0
Solids not fat	229.5	200.8	108.9
Lactose	25.4	22.6	46.7
Total protein (N x 6.38)	194.0	167.9	55.0

Source: Barnicoat, Logan and Grant (1949)

	Colostrum		Milk
Total solids (g/kg)	220.2		180.9
Fat	106.0		69.5
Solids not fat	114.2		111.4
Lactose	45.7		49.8
Crude Protein	59.8		53.6

Source: Peart, Edwards and Donaldson (1979)

6.3 Energy requirements for lactation

Numerous workers have estimated the energy requirements for lactation and calculated the efficiency with which it is utilised. These are best summarised in ARC (1980) where requirements for lactation are separated into three efficiency components.

> "1. The efficiency of utilisation of metabolisable energy for milk secretion in the absence of change in the energy content of the body.
> 2. The efficiency of utilisation of metabolisable energy in promoting gain of energy by the body when lactation occurs simultaneously.
> 3. The efficiency with which the energy of body fat and protein is used to promote milk secretion when the metabolisable energy supplied is less than that needed to achieve zero energy retention."

(See equations in Table 6.4).

To put it simply, energy required for lactation is made up of

a. the energy required for ewe maintenance

b. the energy in the milk

c. the energy required to make the milk divided by the efficiency with which the energy is utilised.

This crude requirement is complicated by partitioning of energy between use for tissue maintenance and growth and use for milk synthesis. The concentration of energy in the diet, the contribution of energy from catabolism of body tissue in the diet and the amount of crude protein present also influence requirement.

The calculation of these values for practical purposes is not simple. The requirements for lactating ewes given in MAFF (1975) resulted in severe undernourishment of ewes as shown by Robinson (1980) (Table 6.5). Cowan et al (1979) showed that large energy losses occurred in ewes in early

Table 6.4

FASTING METABOLISM 210 KJ/kg $W^{0.75}$

SHEEP over 48 months

Efficiency equations

a. $Y_E/W^{0.75} = k_1 (M_E/W^{0.75}) - a$

b. $M_E/W^{0.75} = (1/k_1) (Y_E/W^{0.75}) + \alpha$ b)

M_E metabolisable energy intake

Y_E Milk energy yield

k_1 Efficiency of utilisation of M_E for lactation

a
α intercepts

Maintenance = $\frac{a}{k_1}$ or $\frac{\alpha}{k_1}$ when $Y_E = 0$

Equation (b) should be used to estimate M_E requirements for a known Y_E.

Equation (a) should be used to estimate Y_E from a known M_E when body energy is in equilibrium.

The best estimate of k_1 would be 0.84.

Table 6.5 The effect of under feeding a diet with a ME and crude protein concentration of 10.5 MJ and 113 gCP/kg dry matter respectively on expected milk yield and body weight loss based on ME intake.

ME intake (MJ/d)	ME intake	
	Milk yield kg/d	Body weight loss g/d
15.6	1.0	0
17.6	1.5	50
19.6	2.0	100
21.5	2.5	150
23.3	3.0	200
25.3	3.5	250

Source: Robinson (1980)

lactation receiving the requirements recommended by MAFF (1975). The reason that this had not been detected previously was because maintenance of liveweight was equated with energy equilibrium. While Cowan et al (1979) showed that energy losses were far greater than suggested by liveweight loss due to hydration of body tissue.

Present recommendations for energy for 40 kg and 75 kg ewes losing no weight are given in Figure 6.2 for different energy concentrations of the diet and at different milk yields.

Further explanation of the dynamics of the protein-energy relationship will be discussed in a later section.

6.4 Protein requirements

Responses in milk yield to increasing crude protein content have been summarised by Robinson (1977). The graph (Figure 6.3) shows that little response was obtained above 110 and 120 gCP/kgDM , but it is notable that, at any particular protein content a wide range of milk yields were measured by different workers.

Until recently protein requirements had been estimated by the factorial method (ARC, 1965) summing requirements for urinary, faecal losses, protein in tissue deposition, foetuses, milk, wool and skin. While logical, the ARC (1965) system had its deficiencies. Digestible crude protein did not take account of losses in the urine which may occur if ammonia is released rapidly in the rumen.

The new system described by ARC (1980) considers the actual protein supply which the ruminant uses, that is the amino acids supplied to and absorbed in the small intestine.

Figure 6.2 Effect of metabolisable energy intake on milk yield for ewes of 40 and 75 kg liveweight with zero weight loss

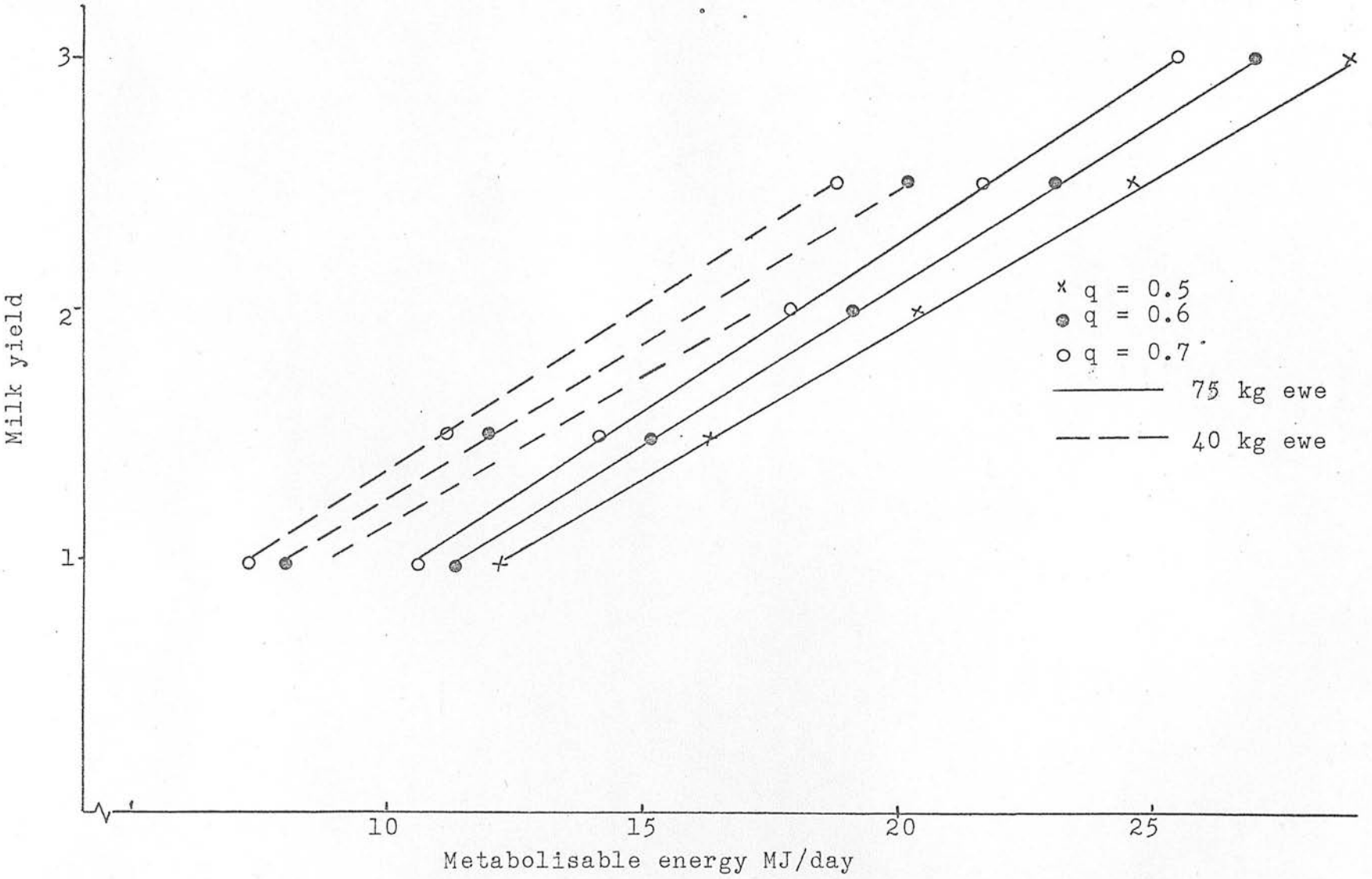
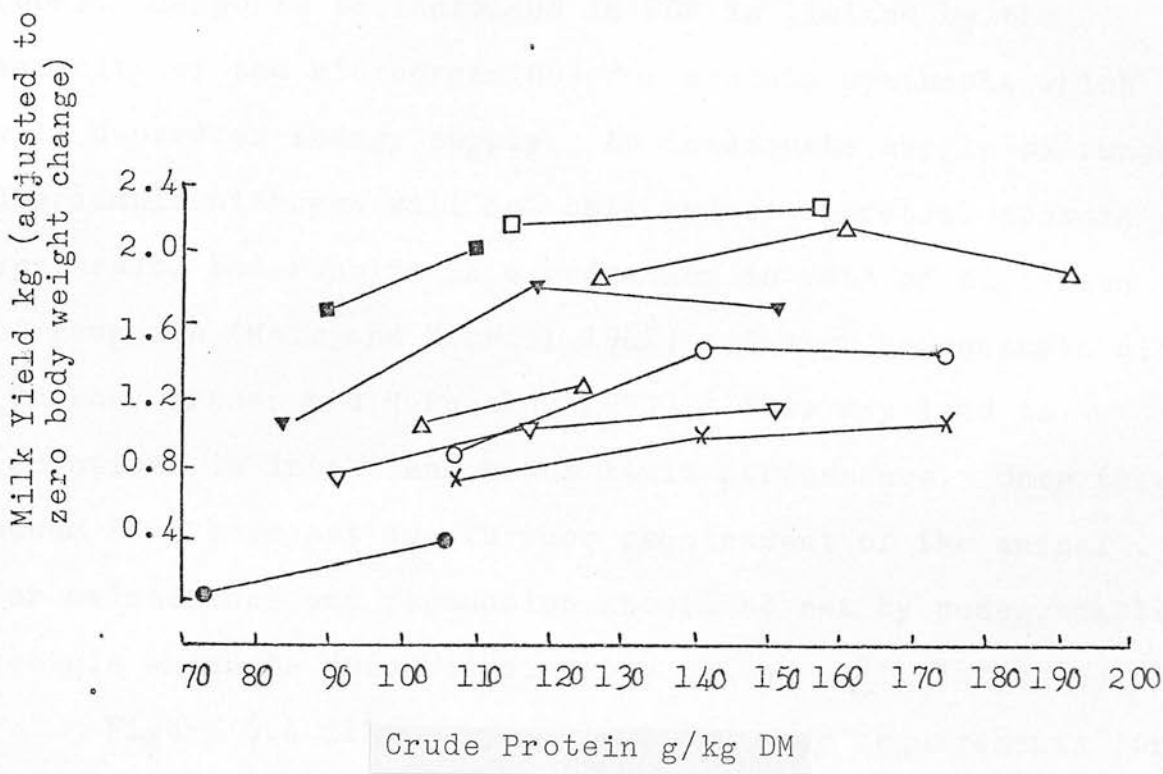


Figure 6.3



× Hogue (1967) Expt 1 (Singles)
○ (Twins)

▽ Hogue (1967) Expt 2 (Singles
▼ (Twins)

● Whiting, Slen and Bezeau (1952) Singles

▲ Wright, Pope and Phillips (1962) Singles and twins

■ Robinson and Forbes (1970) Twins

△ Robinson, Fraser, Gill and McHattie (1974) Twins

□ Calderton, Cortes, Robinson, McHattie and Fraser (1977) Twins

These come from two sources, firstly microbial protein which is synthesised by microorganisms from ammonia and amino acids. The dietary nitrogen which provides these can be in the form of non-protein nitrogen or protein. Secondly the small intestine receives protein which has resisted degradation in the rumen. Hence the two components of dietary protein are rumen degradable protein (RDP) and undegradable protein (UDP). Response to increases in RDP is limited by the capacity of the microorganisms for protein synthesis which will depend on energy supply. An inadequate supply of rumen degradable nitrogen will not only reduce microbial protein synthesis, but results in a reduction in rate of digestion of roughage (Moir and Harris, 1962) and high concentrate diets (Ørskov, Fraser and McDonald, 1972). This may lead to reductions in intake and hence limit performance. Once these needs have been met any further requirement of the animal for maintenance and production should be met by undegradable protein which is absorbed directly in the small intestine.

Figure 6.4 illustrates the increasing requirements for RDP and UDP with increasing milk yield. It is notable that, while the total protein requirement is almost the same for all three energy concentrations, the RDP decreases in proportion to the metabolisability* of the diet.

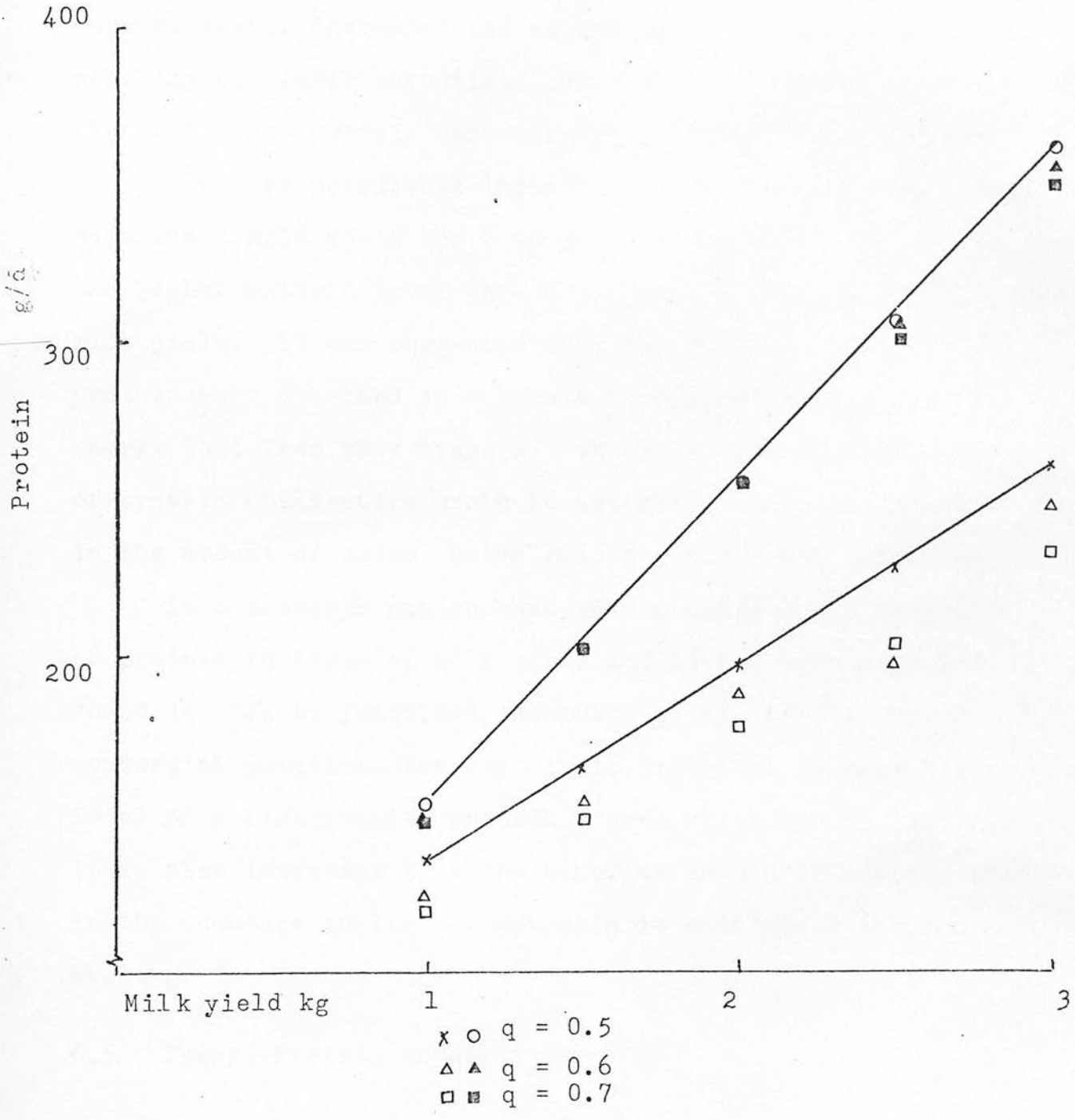
In the lactating ewe demand for protein is likely to exceed the amount that can be supplied by microbial synthesis and responses to UDP are likely.

The response to protein sources of different degradability

---

* metabolisability is the proportion of the gross energy which can be metabolised (GE/ME)

Figure 6.4 Effect of increasing protein intake on milk yield at different levels of metabolisability



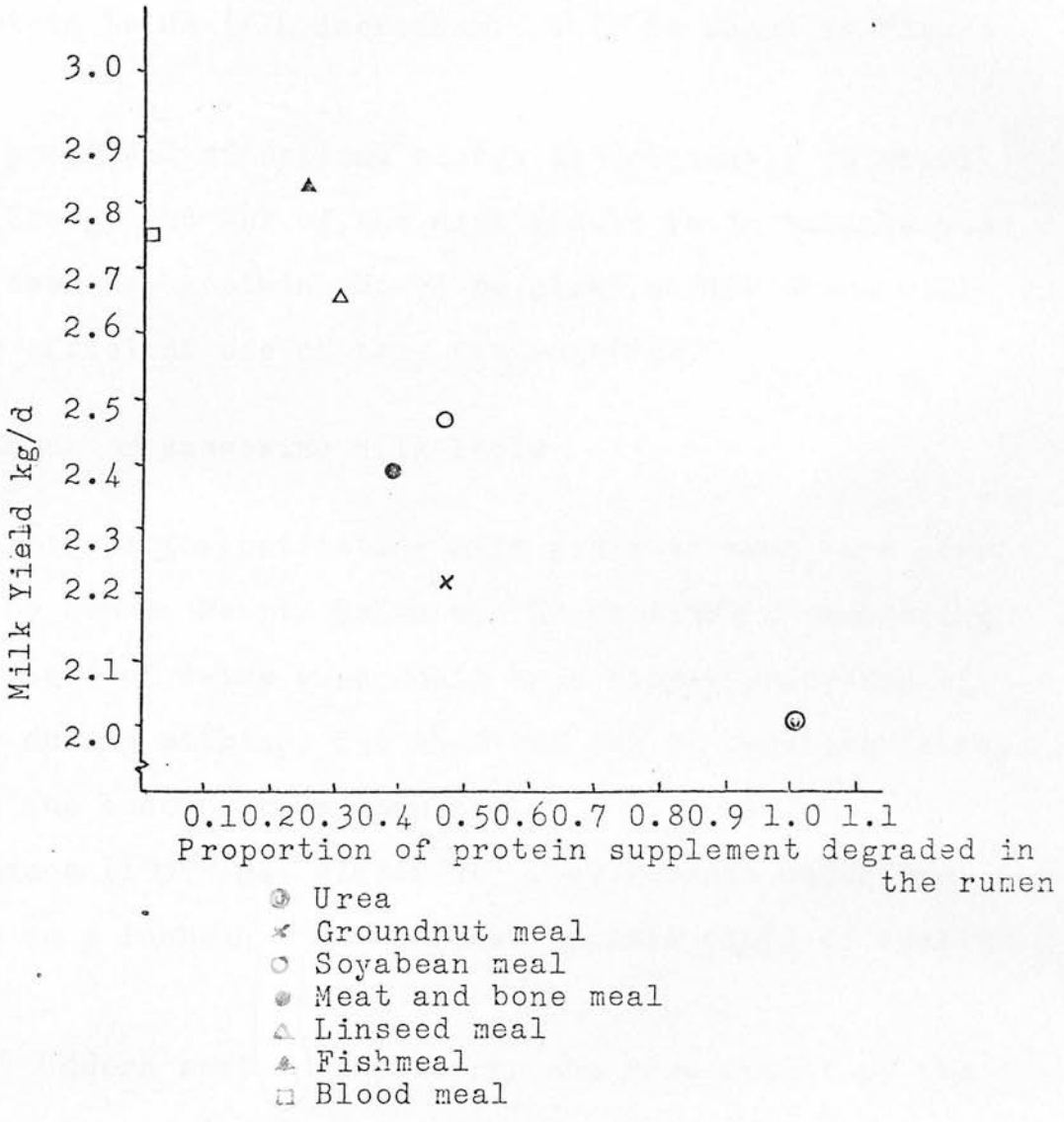
is illustrated in Figure 6.5. As the proportion of the protein supplement degraded increases, so the milk yield falls (Gonzalez et al, 1979). Cowan (1980) discussed the way in which white fishmeal, a protein source with a relatively low degradability, increased the amount of essential amino acids reaching the small intestine. When diets containing 143 g/kg DM or 116g/kgDM crude protein were compared, the former was found to give a more persistent lactation. The lower protein level maintained milk yield for 2 to 3 weeks then declined, while the higher protein level gave a later peak and a more sustained milk yield. It was suggested that responses to additional protein were obtained as a result of more efficient use of energy lost from body tissues. The increases in efficiency of protein utilisation would be associated with an increase in the amount of amino acids reaching the small intestine.

In a research environment with prolific ewes responses to protein in terms of milk yield and lamb growth rate are found and can be justified (Robinson et al, 1979). In commercial practice, however, it is important to know the level of a high quality protein source which can be justified. It is also important that the benefits should be reaped, that is the advantage in lamb weight gain is maintained until weaning.

6.5 Energy-Protein interaction

The basic link between energy and protein in the ruminant is that they are both required for microbial protein synthesis (ARC, 1980). The microorganisms require energy to make microbial protein from ammonia and amino acids in the rumen. If either energy or the nitrogen source is low,

Figure 6.5 Effect of degradability of protein source on milk yield at approximately the same N intake (4.7 g/d)



Source : Gonzalez, Robinson, McHattie and Mehrez (1979)

protein synthesis will be restricted. Figure 6.6 shows the effect of increasing protein intake on production at different energy intakes. It can be seen that production can only be optimised when protein and energy are in balance. Robinson (1980) described the minimum protein intake required to optimise milk yield at any given metabolisable energy (ME) intake. Also as milk yield increases the minimum ratio of crude protein to ME (MJ) increases. This is shown in Figure 6.7.

In practical situations energy is frequently in short supply. Energy and RDP of the diet should be in balance and any supplementary protein should be given as UDP which will stimulate efficient use of body fat reserves.

6.6 Methods of assessing Milk Yield

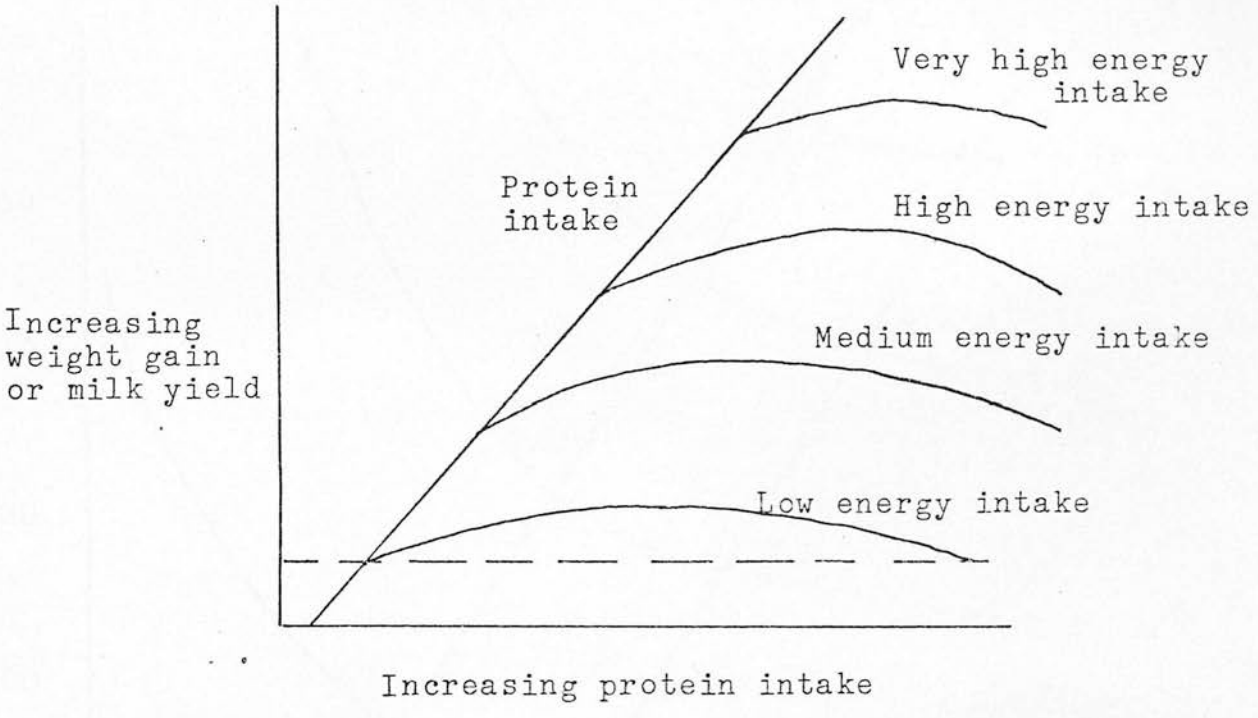
Techniques for estimating milk yield in ewes have been reviewed by Doney, Peart, Smith and Louda (1979). Measuring the milk yield of dairy ewes would be a simple procedure of recording during milking, but when the ewe is suckling lambs, the technique becomes more complex.

McCance (1959) has stated the requirements which are necessary in a technique for estimating milk yield of suckled sheep.

1. Udders must be emptied to the same extent at the start and end of the period of measurement.
2. The period of measurement must be representative of the period to which it is extrapolated.
3. The method must not affect the rate of milk secretion.

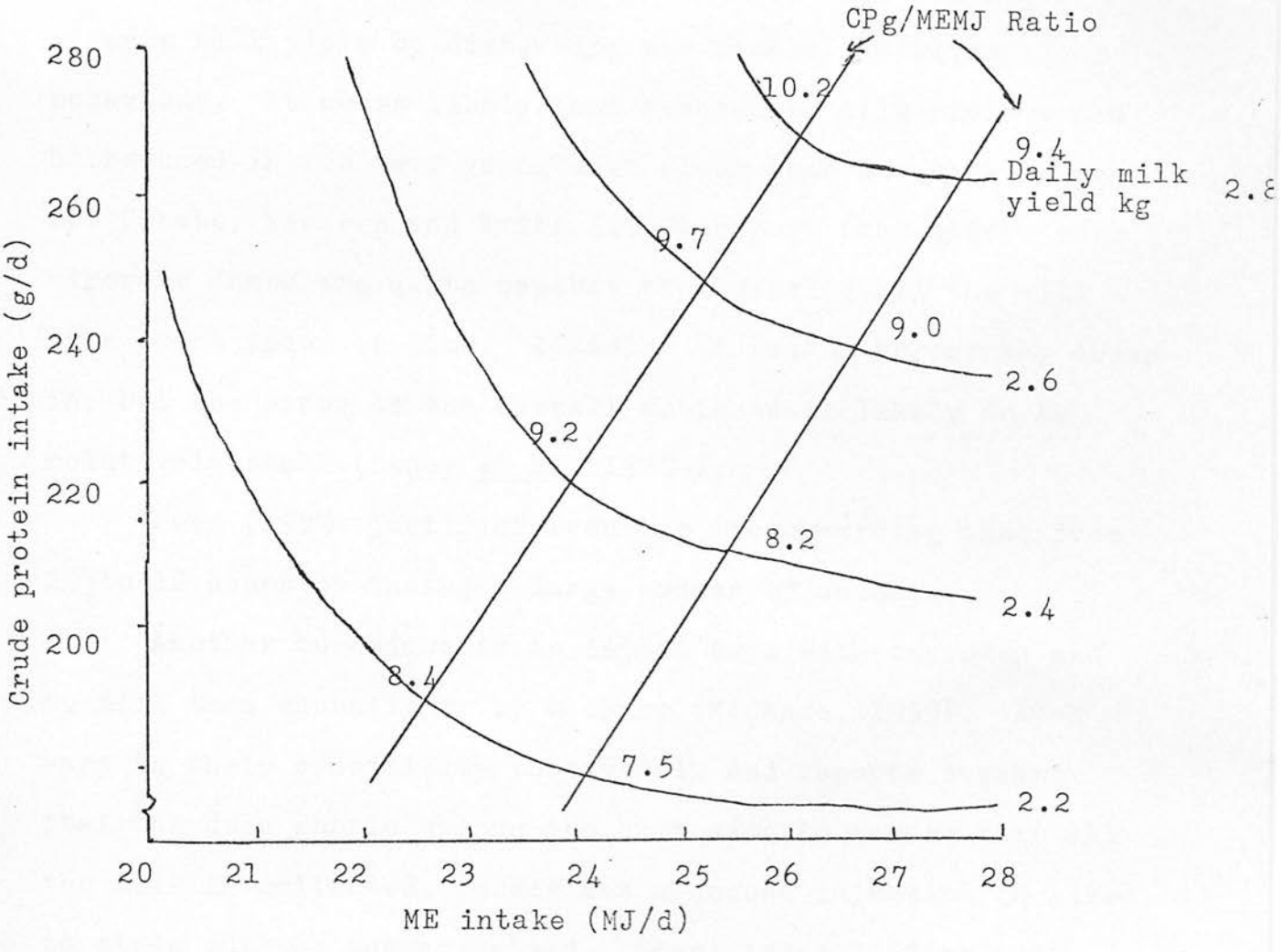
There are a number of ways in which to measure the milk

Figure 6.6 General graph to illustrate the response of growing or lactating ruminants to the combined effect of energy and protein intake



Source ARC (1980)

Figure 6.7 Response of milk yield to alterations in dietary CP and ME for 60 kg ewes suckling twin lambs



Source: Robinson (1977)

yield of a ewe suckling lambs. Firstly the lamb can be removed from the ewe and allowed restricted access for 24 hours being weighed before and after each suckling (Wallace, 1948). This is fairly effective once a routine is established, though there is a risk of losing weight by the lamb voiding faeces or urine between weighings. The procedure is time consuming and one day's records are accepted as being representative of the week.

It is difficult to establish whether this technique affects milk yield by disturbing the natural suckling behaviour. It seems likely that records of milk yield would be reduced in the very young lamb (less than one week of age), but Coombe, Wardrop and Tribe (1960) report that older, more vigorous lambs are quite capable of consuming all the milk in a short space of time. A number of random errors may creep in, but the error on the overall estimate is likely to be relatively small.(Doney et al, 1979).

Owen (1957) justified reducing the recording time from 24 to 12 hours by having a large number of animals.

Another technique is to inject ewes with oxytocin and to milk them manually or by machine (McCance, 1959). Ewes vary in their sensitivity to oxytocin and reports suggest that the dose should err on the high side to ensure that all the milk is collected. Sometimes a second injection is given to strip out the mammary gland. Comparisons confirm that yields obtained using this technique were similar to that achieved when a live lamb is suckling.

The use of oxytocin is necessary in order to stimulate milk let down. The udder would be emptied in the same way at the start and end of the period of measurement. The

administration of oxytocin is most effective when it is given intravenously. Intramuscular injections or the use of nasal sprays are less precise (Doney et al, 1979).

It is important to use a sufficiently high dose of oxytocin to elicit the response of milk let down. The reduction in the response of the mammary gland to oxytocin will occur due to stress (Findlay, 1970).

A four hour milking interval was concluded to be the best compromise between allowing minimal denial of milk to the offspring and a consistent estimate of yield. Once accustomed to the procedure the ewes showed little signs of disturbance.

The question arises as to whether the use of high doses of oxytocin in itself influences milk yield. A number of workers (McCance, 1959; Thompson, Paape and Smith, 1973) found no effects on milk secretion. Carry-over effects were mainly found with the prolonged continuous treatment, therefore it can be assumed that high nonphysiological doses of oxytocin administered on one day per week are unlikely to distort the normal lactation pattern.

Briefly, body water dilution techniques are not readily usable as milk is not the only source of body water, and the use of double-antibody techniques with radio-isotopes involve a high level of laboratory commitment to comply with the stringent regulations (Doney et al, 1979).

Techniques used should allow comparison of yields within experiments, but between experiment comparisons would be useful. Oxytocin and double isotope techniques have tended to exceed milk intake measurements in the early weeks of lactation particularly with single lambs (Doney et al, 1979), but

thereafter suckling techniques have exceeded estimates of production from double-isotope methods. Over a six week period the average yields using oxytocin or lamb suckling techniques were not significantly different (Doney et al, 1979).

Indirectly milk yield can be estimated from lamb growth rate assuming little else is consumed (Doney and Munro, 1962). Robinson, Forbes and Foster (1969) have presented a production equation to estimate milk yield from liveweight data. Standard errors are provided to test the accuracy of the method for any particular application.

6.7 Conclusions

In embarking on lactation studies with a view to providing useful information for commercial practice, several basic ideas should be borne in mind.

a. The level of feeding should be considered in the light of what is currently offered in practice.

b. The cost of the response to a particular feeding regime should be assessed, though long-term price changes may alter this.

c. The method of measurement of milk yield should relate to lamb intake.

d. Any valuable responses should persist until the lamb is at a marketable age.

CHAPTER 7

EXPERIMENT 1

7.1 Introduction

Since Wallace (1948) identified that the greatest part of foetal growth occurred in late pregnancy, practice has been geared to feeding supplementary concentrates and hay at this time, to compensate for the lack of herbage. While this may be effective, it may be more economic to rely to some extent on ewes body reserves to partly meet foetal demands.

In a study of the effect of the annual pattern of nutrition of the lowground ewe, Speedy, Black and Fitzsimons (1983) found that birth weight of twin lambs and the live weight and condition of the ewe at lambing were significantly improved by a prolonged flushing period on good quality pasture for 8 compared with 4 weeks before mating. Lamb birth weight was increased by 0.56 kg as a result of a 6.4 kg liveweight difference and 0.8 condition score difference of the ewes at mating. The mean lamb birth weight of the late flushed group (4.16 kg) was acceptable in terms of lamb viability but the higher mean birth weight implies that fewer lambs at the lower end of the weight range fell into the critical "less than 2 kg" category. The difference in ewe liveweight at mating was maintained throughout the gestation period and was only partly reduced by higher concentrate feeding in late pregnancy.

The aim of the present experiment was to examine the effect of extreme body conditions of the ewe at mating, followed by subsequent weight gain or loss, on placental

and foetal development and composition of the ewe at ninety days of gestation.

7.2 Materials and Methods

7.2i Ewes Sixty 5 year old Scottish Halfbred (Border Leicester x Scottish Blackface) were available for the experiment. It was intended that they should follow the pattern of liveweight change illustrated in Figure 7.1.
Management The ewes were housed and individually penned on the 7th August, 1978, at Woodhouselee, Bush Estate, Penicuik, Midlothian. Pens were open metal gates measuring 5 ft x 4 ft 6 in and contained an open-topped metal bin for feed and a 2 gallon plastic bucket for water. Sawdust bedding was provided.

Table 7.1 shows the management plan of the ewes over the winter of 1978-79. Mating was synchronised using intravaginal sponges impregnated with 30 mg of 9 -fluoro-11-hydroxy-17 acetoxy progesterone(G D Searle Ltd). The second oestrous cycle after sponge removal was chosen for mating. Reduced conception rates associated with abnormalities in the cervical fluids had been found when mating occurred in the first cycle after sponge removal.

The Suffolk rams were fitted with harnesses holding Sire-Sine crayons and were moved round the groups twice daily to ensure random mating.

7.2ii Diet and Treatment Ewes were fed daily at 8.00 am, a diet of dried grass pellets of composition shown in Table 7.2. Two batches were used and nutrient intakes were calculated using the appropriate composition. To achieve the two groups of ewes in extreme body conditions at mating,

Figure 7.1

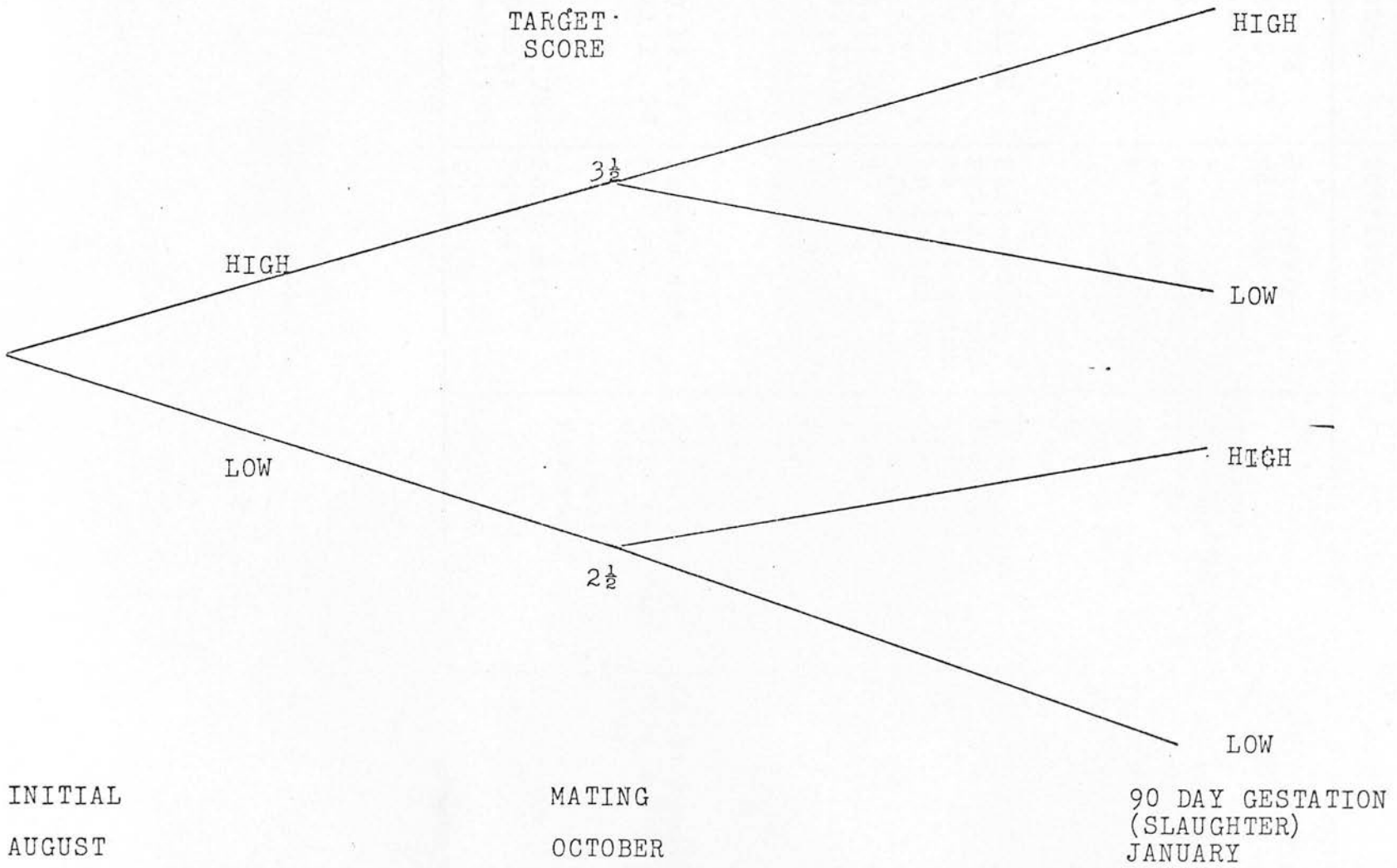

TARGET SCORE
HIGH
3½
HIGH
LOW
LOW
HIGH
2½
LOW
INITIAL
AUGUST
MATING
OCTOBER
90 DAY GESTATION
(SLAUGHTER)
JANUARY

Table 7.1 Management of Halfbred ewes

Date	Nutrition	Reproduction	Housing
7.8.78 15.10.78	Pre-mating rations		Individually penned
4.10.78		Sponges inserted 12 days before	
16.10.78 -26.10.78	Maintenance rations	Sponges removed	"
27.10.78 -4.11.78	"	Mating period- 2nd oestrus after sponge removal	Groups of 10 ewes with 1 ram
5.11.78	Post-mating rations aimed to give gains or losses of 50g/d	Mating dates recorded by observation Sire Sine crayons	Individually penned
12.11.78 -17.11.78	"	Ewes returning to oestrus identified using teaser ram and mated to Suffolk ram as necessary	"
17.11.78 -21.11.78	Maintenance rations	Suffolk rams with all ewes Returns to oestrus recorded	Loose housed with 3 Suffolk rams
21.11.78- 90 days gestation	Post-mating rations		Individually penned

Table 7.2 Chemical composition of dried grass pellets

	Batch 1 7.8.78-10.12.78	Batch 2 11.12.78-22.2.79
Dry matter (as received)g/kg	923	937
Crude protein g/kg DM	121	148
Fibre g/kg DM	313	311
Ash g/kg DM	58	103
Derived:		
Digestible Crude Protein g/kg DM	85	98
Digestibility coefficient %	68	62.9
Metabolisable energy MJ/kgDM	10.6	9.9
Metabolisable energy in fresh MJ/kg	9.75	9.28

the High (H) group were offered the diet ad libitum and the low (L) group were offered 500 g/day initially. When ad libitum intakes rose to 4 kg/day ewes were rationed to 2kg/day and 0.25 kg/day for H, and L groups respectively. Before mating maintenance rations were fed, according to the liveweight achieved, in an attempt to eliminate the effect of rising or declining plane of nutrition on conception rates (Coop, 1962). Feeding allowances are shown in Table 7.3 with an explanation of the method of calculation given in Appendix 1.

After mating each group of ewes was further subdivided in two (H_2 and L_2) and was fed to gain or lose 5 kg by 90 days of gestation. Ration calculation is explained in Appendix 1 and feeding levels are given in Table 7.4.

7.2iii Records Ewes were weighed and condition scored commencing at 1.00 pm on Wednesday of each week. Any feed refusals were collected on Mondays and Fridays, weighed and dry matters of the cumulated refusal and feed were determined at frequent intervals.

7.2iv Slaughter Procedure The ewes were divided into three groups for slaughter, according to mating date (Table 7.5).

Table 7.5 Numbers of ewes slaughtered on each date

Slaughter date	Number of ewes
25.1.79	23
31.1.79	24
22.2.79	12

Table 7.3 Maintenance allowances* for ewes over mating period

Feeding Level No	1	2	3	4	5	6	7	8	9	10
Liveweight range kg	60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100	100
Allowance of dried grass pellets g/day	655	725	780	815	865	915	960	1005	1070	1125

* Calculated from MAFF (1975)

Table 7.4 Allowance for ewes in the early to mid pregnancy period

	Loss			Gain				
Feeding level no	1	2	3	4	5	6	7	8
Liveweight range	70	70-80	80-90	90	70	70-80	80-90	90
Allowance of dried grass pellets g/day	560	660	750	855	1155	1245	1350	1460

The range of gestation date at slaughter was 87 to 92 days.

On the morning of slaughter, ewes were not fed. They were weighed, condition scored and transported to Gorgie Abattoir, Edinburgh. The sheep were stunned by captive bolt pistol and bled from the major vessels of the neck. A team collected and weighed blood, pelt, head and feet, which were then discarded. The carcass was weighed whole, halved down the middle of the spinal column and the left half retained. The entire alimentary tract, pluck and intact uterus were collected in bags and transported to the Carcass Evaluation Unit on Bush Estate, with the left half of the carcass containing the kidney and channel fat.

The following were recorded: weights of full and empty alimentary tract, pluck, liver, heart, pancreas, spleen, kidney, kidney fat and the half carcass.

The uteri had been cut out at the cervix and were reserved in a cold store until dissection took place. The intact uterus was weighed; a mid-line cut was made in each horn and the placenta divided between foetuses by examination of the capillary network. A fine white line can be identified which separates the circulatory systems (Stegeman, 1974). The placenta is not always evenly distributed between foetuses. Maternal and foetal components of the cotyledons were separated, and the number of non functional cotyledon attachment sites at the tip of each horn were counted. Foetal cotyledons were dissected from the placenta, counted and weighed. The empty uterus and placentae were weighed after removal of excess fluid and were sealed in a bag with cotyledons and frozen for processing later. The foetuses

were cut from the umbilical cord as near to the foetal body as possible, weight and sex were recorded and each foetus was photographed on a squared grid. Foetuses were also placed in labelled bags and frozen for later processing. Fluid weight was calculated by difference between the intact uterus and the sum of the dissected parts. The material was minced in four fractions (1) half carcass with kidney and perirenal fat; (2) empty alimentary tract, pluck, liver, heart, pancreas, spleen (non carcass fraction) ; (3) the uterus, placentae and cotyledons (the adnexa) and (4) foetuses. The half carcass was cut up using a band saw and the pieces were minced twice through a Wolfking mincer using plates with hole diameter 13 mm and 5 mm. The homogenate was thoroughly mixed and 3 x 1 kg samples were taken and stored, double wrapped in labelled plastic bags in the deep freeze. The non carcass components were minced and sampled in the same way. The mincer was not cleaned out between samples, but about 1 kg of the initial mince produced, containing the last of the previous sample, was discarded. Fractions 3 and 4 were minced in a smaller mincer through a plate with hole diameter 1.5 mm. Again material was minced and 3 samples were taken which were normally less than 1 kg because less material was available. This time the mincer was cleaned between samples.

7.2v Chemical analysis Oven dry matters were determined by thoroughly mixing and subsampling the thawed sample. Approximately 50 g was accurately weighed into each of four pre-weighed foil containers. These were dried in an oven at 95 ^{o}C until two consecutive weights were within 0.05 g. A mean dry matter was obtained from the four results. The

remainder of the chemical analysis was carried out by the Central Analytical Laboratory of the East of Scotland College of Agriculture.

Dry matter: A homogenous sample of thawed "meat" was weighed, freeze-dried, milled and stored for further analysis.

Determined fat: Fat was extracted in the Soxhlet apparatus using petroleum ether from a sample dried at 60 °C (MAFF, 1973).

Calculated fat: The solvent used in the chemical determination of fat extracts the minimum amount of fat, but is a good general purpose solvent for a broad spectrum of analyses. A second estimate of fat was made by apportioning the energy between the more accurately determined, protein and fat. Energy contents of protein and fat were assumed to be 23.6 and 39.3 MJ/kg respectively. The equation used was:

$$\text{Calculated fat} = \frac{(GE - 0.1475N)}{0.0393}$$

Where GE = gross energy and N = nitrogen (Whittemore, Taylor and Moffat, 1976). It should be applied when the sum of the chemical components using ether extract is greater than 0.05 above or below 1.00. Its use for foetal material where a portion of the energy is attributable to glycogen would not be justified.

Ash: Ash was determined by following the procedure in MAFF (1973) except that a temperature of 550 °C was used.

Gross energy: Gross energy was determined using a Gallenkamp adiabetic bomb calorimeter.

Nitrogen: Nitrogen was determined following a procedure similar to that described by Crooke and Simpson (1971).

The first stage involved a Kjeldahl digestion of the sample using potassium sulphate to increase the boiling point and copper sulphate catalyst. The second stage is an automated determination using a discrete system of analysis and a colorimetric procedure for ammonia nitrogen.

Protein: Protein was derived by multiplying nitrogen by 6.25.

7.2vi Statistical methods The results were analysed as a 2 x 2 factorial experiment with two pre-mating and two post-mating results. The Genstat Statistical package (Lawes Agricultural Trust, 1980) was used to carry out analyses of variance.

7.3 Results

Of the 60 ewes which began the experiment, 33 with pairs of twins and 9 with single foetuses were used in the analysis, giving a total of 42 ewes' data. Twelve ewes were barren, 2 ewes had triplets and one ewe died before mating of Pasteurella pneumonia. Only 3 of the 12 ewes which returned to oestrus conceived; 2 bore twins and one bore a single, but the ewes had commenced post-mating treatment before mating, also their slaughter date was delayed because of industrial action. Their lack of conformity led to the decision to exclude them from the analysis.

7.3i Intakes There was a low incidence of refusal on the high level of feeding and no refusals occurred on the low level. The dry matter intakes were calculated knowing

fresh intake and the concentration of dry matter in the feed and refusal. A constant nutrient composition was assumed for each batch of dried grass pellets.

Nutrient intakes before mating are given in Table 7.6. The mean over the period for the L_1 group was about a quarter of the H_1 group. Post-mating the intake of the L_2 ewes was approximately half that of the the H_2 group (Table 7.7). There was a slight difference due to pre-mating treatment, because allowance had been adjusted according to liveweight at mating.

7.3ii Liveweights and condition scores Initial liveweights and condition scores were similar for each group, but the weights and scores at mating and 90 days gestation have been adjusted by covariance or initial state. At mating a difference of 15 kg and 0.5 units of condition score ($p < 0.001$) became evident between the groups (Table 7.8).

Liveweight and condition score at 90 days of gestation were significantly influenced ($p < 0.001$) by both pre- and post-mating treatment. From mating the H_1H_2 and L_1H_2 gained about 5 and 9 kg respectively, while the H_1L_2 and L_1L_2 groups lost about 7 and 5 respectively.

The desired pattern of weight change had been achieved with the H_1L_2 and L_1H_2 groups converging.

7.3iii Weights of body components The weights of the non carcass components are given in Table 7.9.

Blood, feet, head and pelt were not chemically analysed, but their weights showed significant differences. Head and feet weights may have been influenced by the exact point of

Table 7.6 Mean daily nutrient intake of Halfbred ewes before mating (7.8.78 - 23.10-78)

Treatments	HH	HL	LH	LL
Replicates	9	11	13	9
Mean daily intake g/d				
Dried grass pellets	1510	1580	410	400
Dry matter	1390	1460	380	370
Crude protein	170	180	50	40
TCA fibre	440	460	120	120
Ash	80	80	20	20
Digestible crude protein	120	120	30	30
Metabolisable energy MJ/d	14.8	15.4	4.0	3.9

Treatments	Single treatment effects			
	Premating		Post-mating	
	H	L	H	L
Replicates	20	22	22	20
Mean daily intake g/d				
Dried grass pellets	1550	400	860	1020
Dry matter	1430	370	790	940
Crude protein	170	50	100	110
TCA fibre	450	120	250	300
Ash	80	20	50	50
Digestible crude protein	120	30	70	80
Metabolisable energy MJ/d	15.1	4.0	8.4	10.0

Table 7.7 Mean daily nutrient intake of Halfbred ewes after mating (30.10.78 - 25 or 31.1.79)

Treatment	HH	HL	LH	LL
Replicates	9	11	13	9
Mean daily intake g/d				
Dried grass pellets	1290	720	1180	580
Dry matter	1200	670	1090	540
Crude protein	160	90	150	70
TCA fibre	370	210	340	170
Ash	100	60	90	50
Digestible crude protein	110	60	100	50
Metabolisable energy MJ/d	12.2	6.8	11.1	5.5

Treatments	Single treatment effects			
	Premating		Post-mating	
	H	L	H	L
Replicates	20	22	22	20
Mean daily intake g/d				
Dried grass pellets	960	950	1220	660
Dry matter	890	880	1140	610
Crude protein	120	120	160	80
TCA fibre	280	270	350	190
Ash	80	70	100	50
Digestible crude protein	80	80	110	60
Metabolisable energy MJ/d	9.1	9.0	11.6	6.3

Table 7.8 Liveweights and conditions scores of ewes initially at mating and prior to slaughter

Treatments	HH	HL	LH	LL	Interaction SE of the difference Min-rep	Max-min	Sig.
Replicates	9	11	13	9			
Initial liveweight	79.2	81.1	82.0	80.1	3.16	2.91	NS
Condition score	3.6	3.4	3.6	3.2	0.20	0.18	NS
Mating liveweight	84.2[a]	84.7[a]	70.7[b]	67.7[b]	3.41	3.13	NS
condition score	3.1[a]	3.3[a]	2.6[b]	2.4[b]	0.15	0.14	NS
90 day liveweight	89.8[a]	78.0[b]	80.0[b]	62.4[c]	3.90	3.59	NS
condition score	3.2[a]	2.7[b]	2.9[b]	2.2[c]	0.14	0.13	NS

Treatments	Main Treatment Effects							
	Premating				Postmating			
	H	L	SE of the difference	Sig.	H	L	SE of the difference	Sig
Replicates	20	22			22	20		
Initial liveweight	80.2	81.2	2.06	NS	80.8	80.7	2.08	NS
condition score . .	3.5	3.4	0.13	NS	3.6	3.3	0.13	NS
Mating liveweight	84.5	69.5	2.22	***	76.2	77.1	2.24	NS
condition score	3.2	2.5	0.10	***	2.8	2.9	0.10	NS
90 day liveweight	83.3	72.8	2.54	***	84.0	71.0	2.57	***
condition score	2.9	2.6	0.09	***	3.0	2.5	0.09	***

Table 7.9 Weight of components of the maternal non carcass

Treatments	HH	HL	LH	LL	Interaction SE of the difference Min-rep	Max-min	Sig.
Replicates	9	11	13	9			
Weight of non-analysed parts kg							
Blood	3.94[a]	3.54[b]	3.54[b]	3.00[c]	0.159	0.146	NS
Feet	1.46[a]	1.35[b]	1.31[b]	1.25[b]	0.057	0.052	NS
Head	3.41[a]	3.28[ac]	3.34[a]	3.12[c]	0.111	0.102	NS
Pelt	7.99[a]	6.60[b]	6.29[b]	4.77[c]	0.397	0.366	NS
Sum of above	16.80[a]	14.78[b]	14.48[b]	12.15[c]	0.518	0.477	NS
Weight of analysed parts							
Pluck	2.86[a]	2.54[b]	2.54[b]	2.09[c]	0.144	0.133	NS
Liver	1.05[a]	0.97[a]	0.98[a]	0.73[b]	0.110	0.101	NS
Kidney	0.09[a]	0.08	0.08	0.07[b]	0.005	0.004	NS
Kidney fat	0.51[a]	0.47[a]	0.52[a]	0.18[b]	0.142	0.131	NS
Heart	0.37[a]	0.35[a]	0.34[b]	0.30[c]	0.015	0.013	NS
Pancreas	0.09[a]	0.08[a]	0.09[a]	0.06[b]	0.012	0.011	NS
Spleen	0.15[a]	0.14[a]	0.13[a]	0.11[b]	0.015	0.14	NS
Gastro-intestinal tract	18.68[a]	16.98[a]	17.63[a]	13.96[b]	1.173	1.080	NS
Gastro-intestinal contents	10.84	10.51	10.80	9.02	1.071	0.986	NS
Empty gastro-intestinal tract	7.83[a]	6.48[b]	6.40[b]	4.94[c]	0.485	0.446	NS

Treatments	Single Treatment Effects						
	Premating				Postmating		
	H	L	SE of the difference	Sig.	H	L	SE of the diff
Weight of non-analysed parts kg							
Blood	3.72	3.32	0.104	***	3.71	3.30	0.105
Feet	1.40	1.29	0.037	**	1.37	1.30	0.037
Head	3.34	3.25	0.073	NS	3.37	3.21	0.073
Pelt	7.23	5.67	0.259	***	6.98	5.78	0.262
Sum	15.69	13.53	0.338	***	15.43	13.59	0.341
Weight of analysed parts kg							
Pluck	2.68	2.37	0.094	***	2.67	2.35	0.095
Liver	1.00	0.88	0.072	NS	1.01	0.86	0.072
Kidney	0.08	0.08	0.003	NS	0.08	0.07	0.003
Kidney fat	0.49	0.38	0.093	NS	0.51	0.34	0.094
Heart	0.36	0.32	0.010	**	0.35	0.33	0.010
Pancreas	0.09	0.08	0.008	NS	0.09	0.07	0.008
Spleen	0.15	0.12	0.010	**	0.14	0.13	0.010
Gastro-intestinal tract	17.75	16.13	0.765	*	18.06	15.62	0.773
Gastro-intestinal contents	10.66	10.07	0.699	NS	10.82	9.84	0.706
Empty gastro-intestinal tract	7.09	5.74	0.316	***	7.05	5.78	0.320

detachment, although attempts were made to standardise this. Bleeding is known to be variable in its completeness and caution should be exercised in interpreting differences, but heavier ewes in better condition would appear to have more blood. The greatest difference in these components is attributable to the pelt. The pelts of the H_1H_2 group were, on average, 3 kg heavier than the L_1L_2 group ewes. No measure was made of wool growth or skin thickness.

The remaining components, which were chemically analysed, showed similar weight difference trends. More effects were found due to post-mating treatments. The liver and peri-renal fat were heavier in ewes which gained weight (H_2) after mating. The difference in the gastro-intestinal tract of about 2½ kg was attributable to the empty tract rather than its contents. Other components such as the heart, kidney, pancreas and spleen are not normally associated with energy storage, but were apparently heavier in the ewes which experienced more favourable nourishment.

7.3iv Concentration of chemical constituents With the exception of fat, gross energy and dry matter concentration most constituents had higher levels in the poorly nourished ewes (L_1 and L_2). In the carcass (Table 7.10) the differences were significant for post-mating treatment, but the pre-mating treatment gave similar trends.

The L_1L_2 group of ewes were significantly different from the H_1H_2, H_1L_2 and L_1H_2 groups. The changes in the carcass have been most influenced by post-mating treatment.

In the non carcass (Table 7.11) protein and nitrogen

Table 7.10 Concentration of chemical constituents of the carcass

Treatments	HH	HL	LH	LL	Interaction SE of the difference Min-rep	Max-min	Sig.
Replicates	9	11	13	9			
Concentration of chemical constituents g/kg							
Dry matter	544.3[a]	514.9[a]	523.4[a]	437.8[b]	23.20	21.36	NS
Water	455.7[a]	485.1[a]	476.6[a]	562.2[b]	23.45	21.58	NS
Ash g/kg DM	78.5[a]	96.2[a]	77.0[a]	125.8[b]	16.69	15.36	NS
Determined fat	649.5[a]	616.7[a]	646.0[a]	502.2[b]	44.60	41.10	NS
Calculated fat	652.9[a]	600.5[a]	637.9[a]	492.9[b]	45.80	42.20	NS
Nitrogen	42.0[a]	46.6[a]	44.4[a]	56.6[b]	4.42	4.06	NS
Protein	262.4[a]	291.2[a]	277.3[a]	353.4[b]	27.60	25.40	NS
Gross energy MJ/kg	31.85[a]	30.47[a]	31.61[a]	27.71[b]	1.193	1.098	NS

Treatments	Main Treatment Effects							
	Premating				Postmating			
	H	L	SE of the diff.	Sig.	H	L	SE of the diff.	Sig.
Replicates	20	22			22	20		
Concentration of chemical constituents g/kg								
Dry matter	528.1	488.4	15.14	*	532.0	483.2	15.29	***
Water	471.9	511.6	15.30	*	468.0	519.8	15.45	***
Ash g/kg DM	88.2	97.0	10.89	NS	77.6	109.5	11.00	**
Determined fat	631.4	587.1	29.1	NS	647.4	565.1	29.4	**
Calculated fat	624.1	578.6	29.9	NS	644.1	552.1	30.2	**
Nitrogen	44.5	49.4	0.778	NS	43.4	51.1	0.786	**
Protein	278.2	308.4	18.01	NS	271.2	319.2	18.09	**
Gross energy MJ/kg	31.09	30.02	2.88	NS	31.71	29.23	2.91	**

Table 7.11 Concentration of chemical constituents of the non carcass

Treatments	HH	HL	LH	LL	Interaction SE of the diff. Min-rep	Max-min	Sig.
Replicates	9	11	13	9			
Concentration of the chemical constituents g/kg							
Dry matter	467.5^{a}	466.4^{a}	450.8^{a}	396.3^{b}	25.40	23.38	NS
Water	532.5^{a}	533.6^{a}	549.2^{a}	603.7^{b}	26.23	24.14	NS
Ash g/kg DM	18.6^{a}	17.6^{a}	20.5^{a}	43.2^{b}	11.19	10.30	NS
Determined fat	749.4^{a}	736.9^{a}	720.3^{a}	595.5^{b}	42.20	38.90	NS
Calculated fat	768.8^{a}	752.6^{a}	735.1^{a}	607.5^{b}	41.00	37.70	NS
Nitrogen	33.0^{a}	35.4^{a}	35.9^{a}	54.0^{b}	5.46	5.03	*
Protein	206.2^{a}	221.5^{a}	224.6^{a}	337.5^{b}	34.10	31.40	*
Gross energy MJ/kg	35.08^{a}	34.79^{a}	34.19^{a}	31.84^{b}	0.847	0.779	NS

Main treatment effects

	Premating H	Premating L	SE of the diff.	Sig.	Postmating H	Postmating L	SE of the diff.	Sig.
Replicates	20	22			22	20		
Concentration of chemical constituents g/kg								
Dry matter	466.9	428.5	16.57	*	457.6	434.8	16.75	NS
Water	533.1	571.5	17.11	*	542.4	565.1	17.28	NS
Ash g/kg DM	18.0	29.8	7.30	NS	19.7	29.1	7.37	NS
Determined fat	742.5	669.2	27.60	*	732.2	673.2	27.80	*
Calculated fat	759.9	682.9	26.80	**	748.9	687.3	27.00	**
Nitrogen	34.3	43.3	3.56	*	34.7	43.8	3.60	**
Protein	214.6	270.8	22.30	*	217.0	273.7	22.50	**
Gross energy MJ/kg	34.92	33.23	0.552	**	34.55	33.47	0.558	*

concentrations were significantly higher in the L_1 and L_2 ewes. Ash was only present due to incomplete elimination of the contents from the gastro-intestinal tract and was only significantly higher in the L_1L_2 ewes than the other groups. Fat, nitrogen, protein and energy were influenced by both pre- and post-mating treatment, while dry matter and water concentrations were only affected by pre-mating treatment, in contrast to the carcass. In addition protein and nitrogen showed a significant interaction between pre- and post-mating treatments. Calculated fat was not appropriate for non carcass composition because of the energy contributed by glycogen in the liver.

7.3v Weights of chemical constituents Weights of chemical constituents were generally influenced by both pre- and post-mating treatment. All constituents of the carcass were heavier on the H_1 and H_2 treatments than the L_1 and L_2 treatments (Table 7.12).

Proportionally carcass weight was about 0.2 lower on the L_2 treatment while energy and fat showed a 0.3 reduction in the same comparison. Differences in the main constituents of muscle and bone that is protein and ash were smaller if present than differences between energy and fat. Also a greater proportional change in energy reserves was evident than would have been indicated by carcass weight.

Similar differences were evident in the weight of non carcass chemical constituents (Table 7.13). The magnitude of differences was less than in the carcass, but again that of fat and energy was greater than nitrogen, protein and ash.

Table 7.12 Weights of chemical constituents of the carcass at 90 days gestation

Treatments	HH	HL	LH	LL	Interaction SE of the difference Min-rep	Max-min	Sig.
Replicates	9	11	13	9			
Weights of chemical contents of carcass kg							
Fresh weight	41.22^{a}	34.59^{b}	35.81^{b}	26.47^{c}	2.927	2.694	NS
Dry matter	22.56^{a}	18.07^{b}	18.93^{b}	11.85^{c}	2.156	1.984	NS
Water	18.67^{a}	16.52^{b}	16.83^{b}	14.62^{c}	0.830	0.764	NS
Ash	1.69^{a}	1.62^{a}	1.38^{b}	1.37^{b}	0.140	0.128	NS
Determined fat	14.80^{a}	11.52^{a}	12.56^{a}	6.35^{b}	1.994	1.836	NS
Calculated fat	14.94^{a}	11.30^{a}	12.39^{a}	6.22^{b}	2.046	1.883	NS
Nitrogen	0.93^{a}	0.80^{b}	0.81^{b}	0.63^{c}	0.046	0.042	NS
Protein	5.79^{a}	5.00^{b}	5.06^{b}	3.96^{c}	0.285	0.262	NS
Gross energy MJ	724.0^{a}	561.9^{b}	606.2^{b}	337.7^{c}	83.5	76.90	NS

Treatments	Main treatment effects							
	Premating				Postmating			
	H	L	SE of the diff.	Sig.	H	L	SE of the diff.	Sig.
Weights of chemical contents of carcass kg								
Fresh weight	37.57	31.99	1.909	**	38.02	30.94	1.929	***
Dry matter	20.09	16.06	1.406	**	20.44	15.27	1.421	***
Water	17.48	15.92	0.541	**	17.58	15.66	0.547	***
Ash	1.66	1.38	0.091	**	1.51	1.51	0.092	NS
Determined fat	13.00	10.02	1.301	*	13.48	9.20	1.314	**
Calculated fat	12.94	9.86	1.335	*	13.43	9.01	1.348	**
Nitrogen	0.86	0.74	0.030	***	0.86	0.72	0.030	***
Protein	5.35	4.61	0.186	***	5.36	4.53	0.188	***
Gross energy MJ	634.8	496.4	54.50	*	654.4	461.0	55.00	**

Table 7.13 Weights of chemical components of the non carcass at 90 days of gestation

Treatments	HH	HL	LH	LL	Interaction SE of the difference Min-rep	Max-min	Sig.
Replicates	9	11	13	9			
Weights of chemical contents of non carcass kg							
Fresh weight	12.35^{a}	10.56^{bd}	10.33^{bd}	8.25^{c}	0.609	0.560	NS
Dry matter	5.78^{a}	4.96^{bd}	4.69^{bd}	3.31^{c}	0.461	0.425	NS
Water	6.57^{a}	5.60^{b}	5.64^{b}	4.94^{c}	0.288	0.265	NS
Ash	0.11^{a}	0.08^{b}	0.10^{a}	0.08^{b}	0.006	0.005	NS
Determined fat	4.35^{a}	3.71^{bd}	3.37^{bd}	2.21^{c}	0.465	0.428	NS
Calculated fat	4.46^{a}	3.78^{bd}	3.45^{bd}	2.23^{c}	0.467	0.430	NS
Nitrogen	0.19^{a}	0.17^{b}	0.17^{b}	0.15^{c}	0.010	0.009	NS
Protein	1.17^{a}	1.05^{ab}	1.06^{ab}	0.97^{b}	0.062	0.057	NS
Gross energy MJ	203.2^{a}	173.5^{ab}	160.4^{b}	110.6^{c}	18.28	16.83	NS

Treatments	Main treatment effects							
	Premating H	L	SE of the diff.	Sig.	Post-mating H	L	SE of the diff.	Sig.
Weights of chemical contents of non carcass kg								
Fresh weight	11.37	9.35	0.397	***	11.34	9.59	0.401	***
Dry matter	5.33	4.04	0.301	***	5.24	4.27	0.304	***
Water	6.04	5.31	0.188	***	6.10	5.32	0.190	***
Ash	0.09	0.09	0.004	NS	0.10	0.08	0.004	***
Determined fat	4.00	2.82	0.303	***	3.86	3.07	0.306	**
Calculated fat	4.09	2.88	0.305	***	3.96	3.13	0.308	**
Nitrogen	0.18	0.16	0.006	*	0.18	0.16	0.007	*
Protein	1.11	1.01	0.041	*	1.12	1.02	0.041	*
Gross energy MJ	186.9	136.9	11.93	***	181.8	147.0	12.05	**

Weights of constituents have been summed in Table 7.14 to give the overall changes in the analysed maternal body. All show significant difference due to pre- and post-mating treatment, except ash due to post-mating treatment. Comparing the extremes of the H_1H_2 and the L_1L_2 groups, fresh weight was reduced by 0.35, nitrogen by 0.27, determined fat by 0.56 and energy by 0.52. While the full maternal resources of the ewe have not been considered, by excluding blood, head, pelt and feet, the weights of these components suggest that the effects discussed here may have been magnified by their inclusion.

7.3vi Weights of the adnexa components Pre-mating treatment had the effect of increasing the weight of the uterus, fluids and cotyledon numbers significantly (Table 7.15). The placenta and cotyledon weight approach but do not reach significance. When examined separately (Table 7.15a) placenta and cotyledons were heavier per foetus in ewes on H_1 treatment and males had significantly heavier components than females. Post-mating treatment had no effect on any component.

Litter size and to a lesser extent sex have influenced some of the components. In total, weights of uterus, fluids, placenta and cotyledons and number of cotyledons were greater for twins but were not twice the value of singles. Male lambs gave heavier intact uterus and placenta and cotyledon weights.

7.3vii Concentration of chemical constituents in the adnexa No significant differences due to pre- or post-mating

Table 7.14 Weights of chemical components of the maternal body at 90 days of gestation

Treatments	HH[1]	HL[2]	LH[3]	LL[4]	Interaction SE of the difference Min-rep	Max-min	Sig.
Replicates	9	11	13	9			
Weights of chemical contents of maternal body kg							
Fresh weight	53.57[a]	45.15[b]	45.19[b]	34.75[c]			NS
Dry matter	28.34[a]	23.03[b]	23.10[b]	15.34[c]	2.563	2.359	NS
Water	25.23[a]	22.12[b]	22.09[b]	19.41[c]	0.986	0.908	NS
Ash	1.80[a]	1.71[a]	1.42[b]	1.58[a b]	0.139	0.128	NS
Determined fat	19.15[a]	15.23[a]	15.55[a]	8.49[b]	2.400	2.209	NS
Calculated fat	19.41[a]	15.08[a]	15.42[a]	8.34[b]	2.459	2.269	NS
Nitrogen	1.11	0.97	0.95	0.81	0.047	0.043	NS
Protein	6.96	6.05	5.95	5.04	0.292	0.269	NS
Gross energy MJ	927.1[a]	735.4[b]	746.7[b]	446.8[c]	99.7	91.7	NS

Treatments	Main treatment effects							
	Premating H	Premating L	SE of the diff.	Sig.	Postmating H	Postmating L	SE of the diff.	Sig.
Replicates								
Weights of chemical contents of maternal body kg								
Fresh weight	48.94	40.28		***	49.38	40.77		***
Dry matter	25.42	19.45	1.672	**	25.72	19.79	1.689	***
Water	23.52	20.83	0.643	***	23.66	20.98	0.650	***
Ash	1.75	1.50	0.090	**	1.61	1.65	0.091	NS
Determined fat	16.99	12.23	1.566	**	17.35	12.39	1.582	**
Calculated fat	17.03	12.09	1.604	**	17.42	12.24	1.620	**
Nitrogen	1.03	0.88	0.031	***	1.03	0.90	0.031	***
Protein	6.46	5.52	0.190	***	6.46	5.62	0.192	***
Gross energy MJ	821.7	605.6	85.1	**	836.9	613.9	65.7	***

Table 7.15 Weights of adnexa components.

Treatments	HH[1]	HL[2]	LH[3]	LL[4]	Interaction SE of the difference Min-rep	Max-min	Sig.
Replicates	9	11	13	9			
Weights of products of conception g	2010[a]	2090[a]	1770[b]	1680[b]			
Intact uterus	5350[a]	5200[a]	4390[b]	4470[b]	282.4	260.0	NS
Empty uterus	960[a]	1050[ac]	880[bc]	830[bc]	94	86	NS
Fluids	1890[a]	1780[ac]	1390[bc]	1510[bc]	183.3	168.8	NS
Total placenta and cotyledons	1050	1040	880	850	100.9	92.9	NS
Cotyledon numbers	116.3	125.0	97.4	105.4	13.20	12.13	NS
Non functional cotyledon numbers	25.2	34.6	38.6	28.7	6.88	6.34	NS

Treatments	Main treatment effects							
	Premating H	Premating L	SE of the diff.	Sig.	Postmating H	Postmating L	SE of the diff.	Sig.
Replicates	20	22			22	20		
Weights of products of conception g	2050	1730		**	1870	1910		
Intact uterus	5260	4420	182.9	**	4750	4870	187.5	NS
Empty uterus	1010	860	61	*	910	950	62	NS
Fluids	1830	1440	118.7	*	1580	1660	121.7	NS
Total placenta and cotyledons	1040	870	65.4	NS	950	950	67.0	NS
Cotyledon numbers	121.1	100.7	8.55	*	105.1	116.2	8.76	NS
Non functional cotyledon numbers	30.4	34.6	4.46		33.1	31.9	4.57	NS

	Effect of sex and litter size							
Replicates	6	3	7	17	9	SE of the diff.	M vs T Sig.	S vs T Sig.
Litter size	1	1	2	2	2			
Sex	M	F	MM	MF	FF			
Weights of products of conception g	1272	1303	2174	2133	1794		*	***
Intact uterus	3150	3140	5440	5360	4760		*	***
Empty uterus	740	720	1020	1009	925	365.3	NS	***
Fluids	1120	1110	1630	1840	1630	237.2	NS	***
Total placenta + cot.	530	580	1150	1120	870	130.6	*	***
Cotyledon numbers	78.3	92.7	116.6	122.4	110.2	17.08	NS	**
Non functional cotyledon numbers	29.7	31.0	25.6	37.4	31.3	8.90	NS	

Table 7.15a Weights of placenta and cotyledons per foetus

Treatments	HH	HL	LH	LL	Interaction SE of the difference Min-rep	Max-min	Sig.
Replicates	16	21	22	16			
Weight of components g							
Placenta	140[a]	130[ab]	130[ab]	110[b]	14.1	13.1	NS
Cotyledons	450	410	390	370	40.6	37.8	NS

	Premating H	L	SE of the difference	Sig.	Postmating H	L	SE of the diff.	Sig.
Replicates	37	38			38	37		
Weight of components g								
Placenta	140	120	9.2	*	140	120	9.3	NS
Cotyledons	430	380	26.4	*	420	390	26.7	NS

	Effects of sex and litter size							
	Sex M	F	SE of the difference	Sig.	Litter size 1	2	SE of the diff.	Sig.
Weight of components g								
Placenta	140	120	9.1	**	150	130	14.1	NS
Cotyledons	440	370	26.2	**	410	400	40.7	NS

treatment in any of the chemical constituents (Table 7.16) though an interaction of treatments ($p < 0.05$) was found for fat, nitrogen and protein.

Twins had lower concentrations of dry matter and energy than singles, but higher concentrations of water and ash. Concentrations of constituents were similar for male and female lambs.

7.3viii Weights of chemical constituents of the adnexa All chemical constituents except fat were heavier in ewes which had been on treatment H_1 compared with those of L_1 (Table 7.17). Post-mating treatment had no significant effect, but there was an interaction effect on protein and nitrogen.

Twin lambs had heavier weights of all components except fat, and male lambs gave higher values for dry matter, water, ash and energy than female lambs.

7.3ix Weight of foetus and chemical constituents Fat weight was the only chemical constituent influenced by post-mating treatment (Table 7.18). All other weights showed no significant effects. In male lambs weights of water, nitrogen, protein and the amount of energy were greater than for female lambs. The single-twin comparison tended to show that singles had higher values than twins but only fat reached significance ($p < 0.05$).

7.3x Concentration of chemical constituents of the foetus The only constituent showing a significant difference was fat concentration in the foetus (Table 7.19) which was increased by high post-mating treatment and in singles compared with twins.

Table 7.16 Concentration of chemical constituents in the adnexa at 90 days of gestation

Treatments	HH	HL	LH	LL	Interaction SE of the difference Min-rep	Max-min	Sig.
Replicates	9	11	13	9			
Concentration of constituents g/kg							
Dry matter	126.5	130.4	130.4	130.2	3.80	3.50	NS
Water	873.5	869.6	869.6	869.8	3.80	3.50	NS
Ash g/kg DM	78.8	79.0	77.3	75.9	3.51	3.23	NS
Determined fat	106.3	92.8	90.8	107.1	11.79	10.86	NS
Nitrogen	122.2	124.6	125.0	122.3	1.97	1.81	NS
Protein	765.0	778.7	781.2	764.6	12.30	11.32	NS
Gross energy MJ/kg	22.2	22.0	22.0	22.3	0.23	0.21	NS

Treatments	Main treatment effects							
	Premating H	L	SE of the diff.	Sig.	Postmating H	L	SE of the difference	Sig.
Replicates	20	22			22	20		
Concentration of constituents g/kg								
Dry matter	128.7	130.3	2.46	NS	128.8	130.3	2.52	NS
Water	871.3	869.7	2.46	NS	871.2	869.7	2.52	NS
Ash g/kg DM	78.9	76.7	2.27	NS	77.9	77.6	2.33	NS
Determined fat	98.9	97.5	7.64	NS	97.2	99.2	7.83	NS
Nitrogen	123.6	123.9	1.27	NS	123.9	123.6	1.31	NS
Protein	772.5	774.4	7.97	NS	774.6	772.4	8.17	NS
Gross energy MJ/kg	22.1	22.1	0.15	NS	22.1	22.1	0.15	NS

	Effect of sex and litter size							
Replicates	6	3	7	17	9	SE of the difference	M vs F Sig.	S vs T Sig.
Litter size	1	1	2	2	2			
Sex	M	F	MM	MF	FF			
Concentration of constituents g/kg								
Dry matter	137.2	135.6	124.1	126.0	133.2	4.91	NS	**
Water	862.8	864.4	875.9	874.0	866.8	4.91	NS	**
Ash g/kg DM	70.6	70.7	82.9	80.1	76.5	4.54	NS	**
Determined fat	79.9	65.2	63.3	60.8	62.6	15.25	NS	NS
Nitrogen	122.9	125.4	121.5	124.2	124.7	2.55	NS	NS
Protein	768.1	784.0	759.5	776.3	779.2	15.91	NS	NS
Gross energy MJ/kg	22.5	22.4	21.9	22.1	22.1	0.29	NS	*

Table 7.17 Weights of chemical constituents of the adnexa at 90 days of gestation

Treatments	HH	HL	LH	LL	Interaction SE of the difference Min-rep	Max-min	Sig.
Replicates	9	11	13	9			
Weight of constituents g							
Fresh	2009^{a}	2091^{a}	1766^{b}	1682^{b}	120.9	111.3	NS
Dry matter	254^{a}	270^{a}	227^{b}	217^{b}	13.6	12.5	NS
Water	1755^{a}	1821^{a}	1539^{b}	1465^{b}	109.1	100.5	NS
Ash	20^{a}	21^{a}	18^{ab}	17^{b}	1.5	1.4	NS
Determined fat	19^{a}	16^{ab}	13^{b}	15^{b}	3.0	2.7	NS
Nitrogen	31^{a}	34^{a}	28^{ab}	26^{b}	1.6	1.5	NS
Protein	195^{a}	210^{a}	177^{ab}	165^{b}	10.2	9.4	NS
Gross energy MJ	5.6^{a}	6.0^{ac}	5.0^{ab}	4.8^{b}	0.31	0.28	NS

Treatments	Single treatment effects							
	Premating H	L	SE of the diff.	Sig.	Post mating H	L	SE of the difference	Sig.
Replicates	20	22			22	20		
Weight of constituents g								
Fresh	2054	1731	78.3	**	1865	1907	80.3	NS
Dry matter	263	222	8.8	***	238	246	9.0	NS
Water	1791	1509	70.7	**	1627	1661	72.4	NS
Ash	21	17	1.0	**	19	19	1.0	NS
Determined fat	17	14	1.9	NS	16	15	2.0	NS
Nitrogen	33	28	1.1	***	29	30	1.1	NS
Protein	203	172	6.6	***	184	190	6.7	NS
Gross energy MJ	5.8	4.9	0.20	**	5.3	5.4	0.20	NS

	Effect of sex and litter size						
Replicates	6	3	7	17	9	M vs F	S vs T
Litter size	1	1	2	2	2	Sig.	Sig.
Sex	M	F	MM	MF	FF		
Weight of constituents g Fresh	1272	1303	2174	2133	1794	156.4 *	***
Dry matter	173	176	270	268	239	17.6 *	***
Water	1099	1127	1905	1865	1555	141.1 *	***
Ash	12	13	22	21	18	1.9 *	***
Determined fat	15	11	17	16	15	3.9 NS	NS
Nitrogen	21	22	33	33	30	2.1 NS	**
Protein	132	138	205	208	186	13.1 NS	***
Gross energy MJ	3.9	3.9	5.9	5.9	5.3	0.39 *	***

Table 7.18 Weight of foetus and chemical constituents

Treatments	HH	HL	LH	LL	Interaction SE of the difference Min-rep	Max-min	Sig.
Replicates	9	11	13	9			
Weight of constituents g							
Fresh	735	688	721	649	45.8	42.6	NS
Dry matter	87	79	85	75	6.9	6.5	NS
Water	648	609	636	574	38.8	36.2	NS
Ash	10	10	10	9	1.0	1.0	NS
Determined fat	6	6	6	5	0.6	0.6	NS
Nitrogen	9	8	9	8	0.7	0.7	NS
Protein	59	53	57	51	4.4	4.1	NS
Gross energy MJ	1.9	1.7	1.8	1.6	0.14	0.13	NS

Treatments	Main treatment effects							
	Premating H	Premating L	SE of the difference	Sig.	Postmating H	Postmating L	SE of the difference	Sig.
Replicates								
Weight of constituents g								
Fresh	709	691	29.8	NS	727	671	30.1	NS
Dry matter	83	81	4.5	NS	86	77	4.6	NS
Water	626	610	25.3	NS	641	594	25.5	NS
Ash	10	10	0.7	NS	10	10	0.7	NS
Determined fat	6	6	0.4	NS	6	5	0.4	NS
Nitrogen	9	9	0.5	NS	9	8	0.5	NS
Protein	56	55	2.9	NS	58	52	2.9	NS
Gross energy MJ	1.8	1.7	0.09	NS	1.8	1.7	0.09	NS

	Effect of sex and litter size							
Replicates	37	38	SE of the difference	Sig.	9	66	SE of the difference	Sig
Litter size					1	2		
Sex	M	F						
Weight of constituents Fresh	736	664	29.6	*	759	692	45.9	NS
Dry matter	86	77	4.5	NS	93	80	7.0	NS
Water	650	587	25.1	*	666	612	38.9	NS
Ash	10	10	0.7	NS	11	10	1.1	NS
Determined fat	6	6	0.4	NS	7	6	0.6	*
Nitrogen	9	8	0.5	*	10	9	0.7	NS
Protein	59	52	2.8	*	62	54	4.4	NS
Gross energy MJ	1.9	1.7	0.09	*	2.0	1.7	0.14	NS

Table 7.19 Concentration of chemical constituents in the foetus

Treatments	HH	HL	LH	LL	Interaction SE of the difference Min-rep	Max-min	Sig.
Replicates							
Concentration of constituents g/kg							
Dry matter	117.2	114.1	116.6	114.7	2.89	2.69	NS
Water	882.8	885.9	883.4	885.3	2.89	2.69	NS
Ash g/kg DM	116.2	123.8	122.7	123.9	4.92	4.58	NS
Determined fat	73.6[a]	71.6	73.9	67.9[b]	2.73	2.54	NS
Nitrogen	108.6	107.4	109.0	108.9	1.31	1.22	NS
Protein	679.0	671.3	681.1	680.8	8.18	7.61	NS
Gross energy MJ/kg DM	21.43	21.36	21.60	21.44	0.231	0.215	NS

Treatment	Main treatment effects							
	Premating H	Premating L	SE of the diff.	Sig.	Postmating H	Postmating L	SE of the difference	Sig.
Replicates								
Concentration of constituents g/kg								
Dry matter	115.4	115.8	1.88	NS	116.8	114.4	1.90	NS
Water	884.6	884.2	1.88	NS	883.2	885.6	1.90	NS
Ash g/kg DM	120.5	123.2	3.21	NS	120.0	123.8	3.24	NS
Determined fat	72.5	71.4	1.78	NS	73.8	70.0	1.79	*
Nitrogen	107.9	109.0	0.85	NS	108.8	108.1	0.86	NS
Protein	674.6	680.9	5.33	NS	680.2	675.4	5.38	NS
Gross energy MJ/kg DM	21.39	21.53	0.151	NS	21.52	21.40	0.152	NS

	Effect of sex and litter size							
Replicates	37	38	SE of the difference	Sig.	9	66	SE of the diff.	Sig.
Litter size					1	2		
Sex	M	F						
Concentration of constituents g/kg								
Dry matter	116.1	115.2	1.87	NS	120.1	115.0	2.90	NS
Water	883.9	884.8	1.87	NS	879.9	885.0	2.90	NS
Ash g/kg DM	120.4	123.3	3.18	NS	121.5	121.9	1.93	NS
Determined fat	71.3	72.5	1.76	NS	78.9	71.0	2.73	**
Nitrogen	109.3	107.6	0.85	NS	107.2	108.6	1.31	NS
Protein	683.2	672.6	5.28	NS	669.7	678.9	8.20	NS
Gross enrgy MJ/kg DM	21.50	21.43	0.149	NS	21.16	21.50	0.232	NS

7.4 Discussion

The hypothesis tested was that ewe nutrition before mating, leading to a difference in ewe body condition, caused a difference in the growth of the foetus. An attempt to distinguish the mechanism by which this operated was made.

No significant difference in foetal weights were apparent at 90 days of gestation; this result was predictable since Robinson (1977) reported that foetal lambs had only achieved about 0.15 of their final birth weight at this stage. However slight differences were evident in favour of the higher level of nutrition and by assuming a relative growth rate of 0.035 birth weight can be predicted using the equation $y = W(a + 1)^{n-1}$ where y is birth weight, a is relative growth rate and n is number of days to parturition.

Table 7.20 Predicted birth weights of foetuses assuming a constant relative growth rate of 0.035

Treatment	Weight at 90 days of gestation W kg	Weight at 145 days Y
H_1H_2	0.735	4.7
H_1L_2	0.688	4.4
L_1H_2	0.721	4.6
L_1L_2	0.649	4.2

The difference at birth was as much as 0.5 kg.

Male lambs were heavier than female lambs ($p < 0.05$) and twin lambs tended to be lighter than single lambs, though the latter difference did not reach significance.

Associated with the difference in weight between sexes were increases in the amount of water, protein and energy in male compared with female foetal lambs ($p < 0.05$). Comparing singles and twins only fat content was higher in the single lamb. Fat content was also higher ($p < 0.05$) for lambs from ewes on the H_2 level of feeding. Possibly these small differences may diverge to become larger at birth when the amount of fat or energy reserves may influence the survival of the lamb.

Without initial and intermediate slaughter groups the ewes can only be compared at one point in time. The relative uniformity of initial liveweight of the groups permits the assumption that the mean composition of each group initially was similar and that differences observed at 90 days of gestation resulted from treatments imposed.

The differences in concentration of chemical constituents in the non carcass occurred as a result of pre-mating and post-mating treatments, while those in the carcass occur mainly as a result of post-mating treatment. Weights of chemical constituents of both carcass and non carcass are influenced equally by pre- and post-mating treatment.

From the table of weights of chemical constituents in the maternal body the largest component of the fresh weight change was fat, the most labile energy reserve. Protein and ash, as components of functional tissue of muscle and bone, change relatively little, though the fact that they have been depleted implies that the degree of undernourishment was relatively severe. Fat was reduced by 0.3 in the low compared with the high groups while protein was reduced by 0.13 in the same comparison. Dry matter reflects the loss

of fat because the latter contains only 0.2 of water, while water reflects the loss of protein which is approximately 0.8 water. In the pregnant ewe a mass of material high in protein and water and low in fat is accumulating and frequently weight stasis or gain is observed. The gain of this "dilute" material masks the loss of energy and fat because of its high water content. An 18.8 kg difference (0.34 of total) in maternal body weight was associated with a 10.7 kg (0.55 of total fat) reduction in fat content and 480.3 MJ (0.52 of energy) reduction in energy content.

Ewes losing liveweight are experiencing changes in body fat and energy of greater magnitude than suggested by the absolute difference in liveweight. The increase in concentration of water partly accounts for this. Liveweight is, therefore, not a good indicator of energy status, of the ewe.

Energy utilisation from the maternal body in late pregnancy has been illustrated by Rattray, Trigg and Ulrich (1979) among others. It is not known whether energy supply to the foetus from the dam is restricted below a certain level of maternal energy, but it is possible that the ewe reqires a minimal amount of fat. Maternal energy may be restricting to the nutrient supply to the growing foetus, had the ewes in the present experiment been allowed to continue to term.

Everitt's work (1964) in Australia has illustrated that undernutrition in early pregnancy reduced foetal growth mediated by the size of the placental structure. Mellor has also found that by surgically removing caruncles or

points of attachment between the maternal and foetal circulations, the growth of the lamb is restricted. Small, but significant ($p < 0.05$) reductions in placenta and cotyledon weights of individual foetuses were observed in the present experiment. Fewer cotyledons were found in the poorly nourished ewes, but generally in this case individual cotyledons were larger. Both basic architecture and blood flow rate through the placenta will determine nutrient supply to the foetus (Stegeman, 1974). It is possible that the lighter placentae and cotyledons, which would be expected to have reached their full size by the end of the second trimester may restrict foetal growth in late pregnancy when the foetus has a high absolute growth rate.

In summary, from the predicted birth weights it seems likely that the level of nutrition before mating and in early pregnancy would have some significant effect on foetal growth. Possible mechanisms for the restriction of foetal growth are reduced nutrient supply because of restricted placental size and secondly restricted availability of energy supply from mobilisation of the dam's body reserves. Everitt (1964) proposed the placenta and cotyledons would have to fall below a critical threshold before any limitation would occur. Further work investigating the growth of the foetus in late pregnancy would be necessary before any firm conclusions could be drawn.

CHAPTER 8

EXPERIMENT 2

8.1 Introduction

The objectives of the experiment were to determine the effects of pre-mating nutrition and energy and protein levels in late pregnancy on the birth weight of the lambs. In addition, changes in maternal composition between the start, mating, 90 days of gestation and term were monitored and weights of the conceptus at 90 days and term were recorded. The previous experiment had shown some effects of nutrition on placental development at 90 days of gestation, but the important product is the lamb at birth, its potential growth and viability.

8.2 Materials and Methods

8.2i Ewes One hundred and six 6-year-old Greyface (Border Leicester x Scottish Blackface) ewes were selected for good teeth and udders from a flock of draft (culled for age) ewes. To these, forty purchased ewes, of similar genotype were added giving a total of 146.

8.2ii Management Initially ewes were blocked by liveweight and ten ewes were selected randomly within blocks for slaughter. The remaining ewes were randomly allocated* to one of two grazing treatments with the aim of producing two groups of ewes of different body condition at mating. The high (H) group were extensively stocked and given access to three paddocks (approximately 2 ha in total) of abundant grass. The low (L) group were stocked in one paddock (approximately

* NB Blocking ewes by liveweight was only carried out in order to select ewes for slaughter, not for allocation to treatment. Hence no blocking component appears in this analysis.

0.7 ha) of shorter pasture.

The management plan in Table 8.1 gives dates of the main events in the experiment over the winter from 1979 to 1980. Mating was synchronised using intravaginal sponges impregnated with 60 mg medroxyprogesterone acetate (Veramix, Upjohn, Ltd) and rams were released at the beginning of the second oestrous cycle after sponge removal.

Over the mating period ewes were divided into three groups, two of 35 ewes and one of 45 ewes which were given approximately equal pasture allowance in the 0.7 acre paddocks. Three rams were allocated to each of the first two groups and four, to the third, larger group. Rams were fitted with harnesses using coloured crayons (Sire Sine) to mark the ewes. Mating dates were recorded daily. The rams were fed a barley-based concentrate during recording and were rotated round the groups of ewes to allow random mating. Fewer ewes were mated than expected one week after turning out the rams and on the 6th November ewes which were unmarked were injected with 3 ml Lutalyse to induce oestrus.

Ewes were housed and individually penned in the same accommodation as the ewes in the previous experiment.

Litter size was determined by X-ray photography at approximately 90 days of gestation in order to balance the groups for slaughter and allocation to late pregnancy treatments.

The 90 days of gestation slaughter was split between 23rd January and the 6th February 1980, because of the spread of mating.

As ewes reached 90 days of gestation and were X-rayed they were allocated to one of three late pregnancy nutrition

Table 8.1 Management of Greyface Ewes

Date	Records	Nutrition	Reproduction	Housing
2.8.79	Ewes weighed and allocated to treatment	Half an abundant (H) and half a restricted pasture (L)		At pasture
15.8.79	Initial group of 10 ewes slaughtered			
18,20. 8.79			Intravaginal sponges inserted	"
3.10.79		Approximately equal pasture allowance 2 x 35 ewes + 3 rams 1 x 45 ewes + 4 rams	All sponges removed. Rams put out with harness.	"
20.10.79- 13.11.79	Mating groups		Recording mating dates	
22.10.79	2 x 11 ewes slaughtered			
6.11.79			3 ml Lutalyse to unmated ewes.	
13.11.79	Blood sample and weigh	Maintenance allowance of hay		Housed and individually penned.
17.1.80 -2.2.80	Started X-raying ewes at 90 days gestation	Ewes allocated to treatment as X-ray results were examined HEHP, LEHP and LELP	Litter size determined	
23.1.80	90 day gestation slaughter groups 2 x 12 ewes	Introduced concentrate feeding gradually. Increments changed weekly. Level determined for ewes of similar parturition date (approx 1 week)		
10.3.80	Ewes slaughtered as they reached 142 days gestation. Lambs removed by Cæsarian			
31.3.80	section. 6 x 10 ewes			

treatments, balancing for litter size and previous treatment. Sixty ewes remained in the last trimester of gestation, the majority carrying twin lambs. From the 10th until 31st March they were slaughtered when they reached 142 (± 1) days of gestation.

8.2iii Diet and Treatment The weights at mating were achieved by subjective assessment of pasture allowance, the aim being to produce ewes in condition score 3½ (H) and 2-2½ (L) at mating. From housing till approximately 100 days of gestation ewes were fed hay of average quality (Table 8.2a) to maintain the liveweight achieved at mating. Table 8.2b shows the five levels fed according to the mean liveweight of the ewe weight strata.

At 100 days of gestation, concentrates were gradually introduced and hay was reduced to 400 g of poor quality material (Table 8.3a). The three treatments were high energy, high protein (HEHP), low energy, high protein (LEHP) and low energy, low protein (LELP). Equal numbers of ewes on H and L pre-mating treatments were allocated to the late pregnancy treatments, giving six different combinations altogether. The analysis of the late pregnancy rations is shown in Table 8.3b.

The HEHP treatment was designed to provide adequate nutrients for maternal maintenance and foetal growth. The LEHP and LELP treatments represented a negative energy balance frequently found in commercial practice and compared the effect of high and low protein in these circumstances.

Concentrate level was increased by increments starting at 150 g/d for the HEHP group and 125 g/d for the LEHP and

Table 8.2 Hay rations in early and mid pregnancy

a. Chemical Analysis of hay I

Determined values	
Dry matter g/kg	829
Crude protein g/kg DM	112
M.A.D. fibre g/kg DM	385
Ash g/kg DM	66
Derived values	
Digestible crude protein g/kg DM	66
Metabolisable energy MJ/kg DM	8.9
Digestibility %	57

b. Hay allowances in mid-pregnancy

Group	A	B	C	D	E
Ewe Liveweight range kg	45-54	55-64	65-74	75-84	85+
Mean liveweight kg	51.7	61.4	69.9	78.9	89.1
Metabolisable energy required for maintenance ($M_m = 1.4 + 0.09W$) MJ	6.05	6.92	7.69	8.50	9.42
Weight of hay kg	0.770	0.885	0.980	1.085	1.200
No of ewes	14	25	33	31	11

Table 8.3 Hay and concentrate composition in late pregnancy

a. Chemical analysis of hay II

Determined values	
Dry matter g/kg	815
Crude protein g/kg DM	68
M.A.D. fibre g/kg DM	344
Ash g/kg DM	64
Derived values	
Digestible crude protein g/kg DM	24
Metabolisable energy MJ/kg DM	9.1
Digestibility %	59

b. Chemical analysis of concentrate

	High Protein	Low Protein
Determined values		
Dry matter g/kg	868	869
Crude protein g/kg DM	203	95
Fibre g/kg DM.	106	118
Ether extract g/kg DM	32	18
Non fatty extracts g/kgDM	561	698
Ash g/kg DM	97	68
Derived values		
Digestible crude protein g/kgDM	162	72
Metabolisable energy MJ/kg	12.0	12.2

LELP groups, rising to 300 g/d and 250 g/d respectively after two days. Thereafter the increment was added weekly to reach 1400 g/d and 1100 g/d for the high energy group and two low energy group respectively. Hay was fed at a rate of 400 g/day to all ewes.

The high protein concentrate was fed to the LEHP group. The low protein concentrate was fed to the LELP group and the HEHP group was fed a greater quantity (to increase energy) of a mixture of high and low protein concentrates to achieve the same intake of protein as the LEHP group. The method of calculation of the ration is given in Appendix 2.

Initially concentrates were fed at 8.00 am followed by chopped hay at 9.30 am, but when the concentrate allowance rose to about 1 kg, two weeks before lambing, it was evenly divided in two and fed at 8.00 am and 1.00 pm. This was necessary after inappetance and dullness was observed in some ewes which was probably the result of acidosis. After several days their health improved.

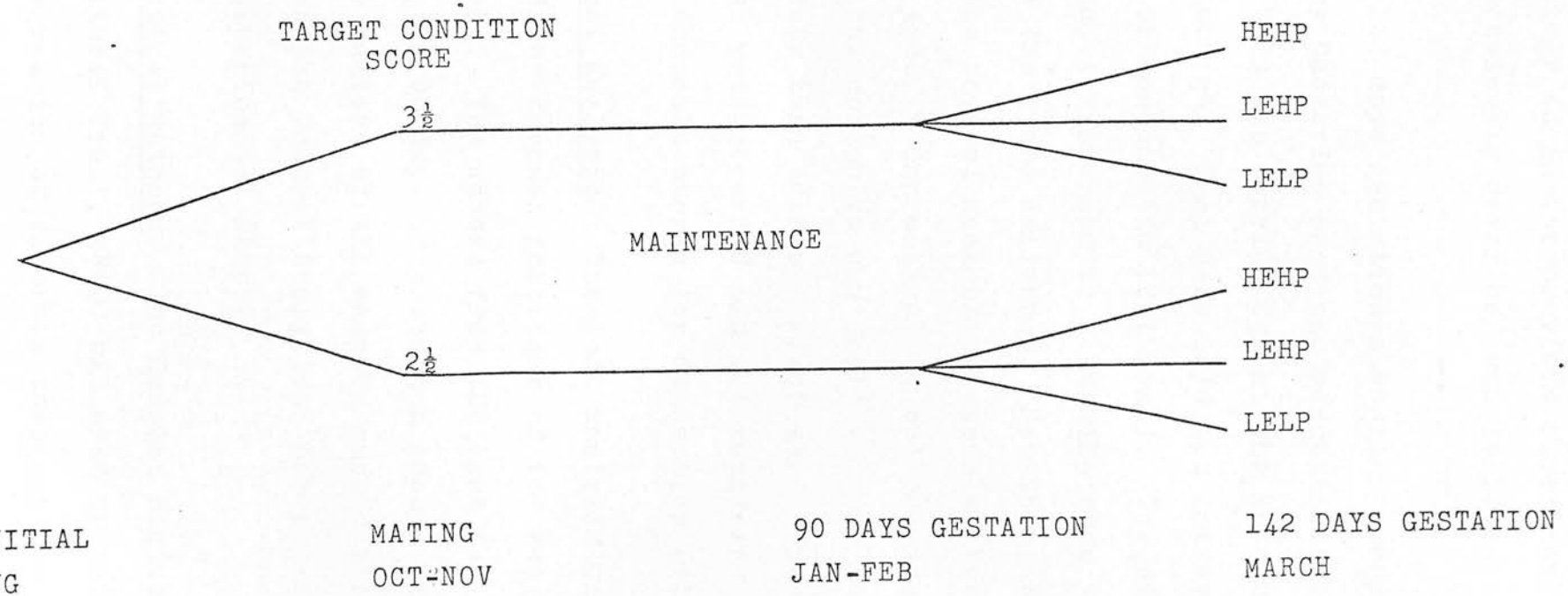
A summary of the treatments is given in Figure 8.1 in the form of a schematic experimental design.

8.2iv Records Ewes were weighed and condition scored at a standard time each week to eliminate effects of variation in gut fill. Any feed refusals were collected and dry matter determined on a cumulated sample.

8.2v Slaughter Procedure Groups of approximately ten ewes per treatment were slaughtered initially, at mating, at 90 days of gestation and at term (142 days of gestation) amounting to a total of 113 ewes.

The first three slaughter operations were carried out

Figure 8.1 Experimental Design



at Gorgie Abattoir as in the previous experiment. The same procedure as previously described was followed in dealing with the material.

For the 142 days gestation slaughter group, the lambs were removed by Caesarian section, resuscitated and reared artifically. This was carried out at the Moredun Research Institute, Edinburgh. Ewes were injected intravenously with a lethal dose of anaesthetic (Euthatal). The uterus was rapidly removed, transferred to a sterile room through a water bath and the lambs delivered. Remaining blood was drained from the severed neck blood vessels, but the nature of the operation made it impractical to collect the blood. The ewe body less conceptus was dealt with as before except that whole rather than half carcasses were minced. Lamb weights and sex were recorded and the remaining conceptus was collected and cold stored for dissection within 36 hours.

8.2vi Chemical analysis Chemical analysis was carried out on carcass and non-carcass fractions of the ewe at the four slaughter points. The adnexa from the last two groups, and the foetuses from the 90 days of gestation groups were analysed.

Oven dry matters of all samples were determined separately from the Central Analytical Laboratory Analysis described in Experimental Chapter 7.

8.2vii Statistical Methods The Genstat Statistical Package (Lawes Agricultural Trust, 1980) was used to analyse the results. A regression of maternal component or constituent on liveweight and condition score was used to produce regression coefficients for the initial, mating and 90 days of gestation slaughter groups. Knowing the liveweight and condition score

of the ewes which completed 142 days of gestation, their composition at the earlier stages was estimated using the coefficients. The estimated values were used to follow the progression of changes throughout the experiment.

The conceptus information was not sensibly correlated to liveweight and condition and the data was analysed in its existing state.

8.3 Results

8.3i Originally it was intended to slaughter 10 ewes per treatment group at each stage. At some points reasons arose to deviate from this. At mating, one ewe retained a sponge, which was surgically removed. The ewe was no longer fit for breeding and was slaughtered. Since this was unlikely to have affected her chemical composition the data was processed and included in the analysis.

At around 90 days of gestation, litter size was identified by X-ray photography. Insufficient ewes carrying twin lambs were found to slaughter ten ewes carrying twins per treatment. The number of ewes slaughtered was increased to eleven ewes per treatment group and ewes with single lambs were included. The high group contained 8 sets of twins and 3 singles, while the low group contained 9 twins and 2 singles. Likewise there were insufficient ewes carrying twins, that is six groups of ten ewes, giving a total of sixty for the late pregnancy treatment. The maximum number of twins were allocated to each group, with the balance being made up by singles. In the event of slaughter some triplets were also present. The analysis was adjusted by covariance for litter size and sex.

8.3ii Intakes Hay intakes in mid pregnancy are given in Table 8.4. The differences arose because rations were allocated according to liveweight attained at mating. The energy intakes were somewhat below the calculated "maintenance" allowance.

Some litter sizes were not correctly predicted by X-ray, and intakes of the groups (Table 8.5) are unadjusted means. The feed and nutrient allowances were not statistically analysed since intakes were restricted. When differences were imposed they were below the animals' appetite limit and only soiled material was refused.

In late pregnancy crude protein intakes followed the planned allowances, but metabolisable energy intakes showed a difference of 1 MJ between the LEHP and LELP treatments and a further increase of only 1.6 to 1.8 MJ between the LEHP and HEHP groups. This may have had some confounding effect on the protein treatments. The main effects have been assumed to be attributable to protein.

8.3iii Initial slaughter group The initial liveweight and condition score of the ewes slaughtered at term were not significantly different (Table 8.6). Weights of all the components were not different showing that at the start of the trial the treatment groups had been fairly standard and that subsequent differences may be accounted for by treatment.

Likewise the concentrations of chemical constituents in the carcass and non-carcass showed no significant differences (Table 8.7) nor did the weights of chemical constituents (Table 8.8).

Together the estimates of composition from liveweight

Table 8.4 Daily nutrient intake in mid pregnancy of ewes slaughtered at 142 days of gestation

Pre-mating	High			Low		
Late pregnancy						
Replicates	HEHP	LEHP	LELP	HEHP	LEHP	LELP
Fresh (hay) g	1070	1063	1047	906	900	975
Dry matter	887	881	868	751	746	808
Organic matter	837	832	819	709	705	763
Crude protein	99	99	97	84	84	91
Digestible crude protein	58	58	57	49	49	53
Fibre	341	339	334	289	287	311
Ash	59	58	57	50	49	53
Metabolisable energy MJ	7.8	7.8	7.7	6.6	6.6	7.2

Table 8.5 Daily nutrient intake in late pregnancy of ewes slaughtered at 142 days of gestation

Pre-mating Late Pregnancy	High			Low		
	HEHP	LEHP	LELP	HEHP	LEHP	LELP
Replicates	10	10	9	10	11	11
Fresh hay I g						
hay 2						
conc A						
conc B						
Total	1342	1208	1080	1357	1196	1080
Dry matter g	1140	1023	914	1153	1013	914
Organic matter	1052	940	857	1064	931	857
Crude protein	157	155	77	159	154	77
Digestible crude protein	114	113	48	115	112	48
Fibre	213	200	192	215	198	191
Ash	75	67	61	76	67	61
Metabolisable energy MJ	12.6	11.1	10.0	12.8	11.0	10.0

Table 8.6 Estimated initial weight of components of ewes slaughtered at term from liveweight and condition score

Pre-mating	High			Low			SE of the difference						
Late pregnancy	HEHP	LEHP	LELP	HEHP	LEHP	LELP	Premating		Late Pregnancy			Interaction		
Replicates	10	10	9	10	11	11			Min-rep	Max-min		Max-min	Max-rep	
Liveweight	73.85	74.55	74.33	74.00	73.82	73.41	1.73	NS	2.134	2.108	NS	3.033	2.878	NS
Condition score	2.90	2.90	2.89	3.20	2.86	2.77	0.10	NS	0.124	0.123	NS	0.177	0.168	NS
Weight of component									Min rep	Max-min		Max-min	Max rep	
Carcass	32.59	32.89	32.73	34.60	32.35	31.58	1.207	NS	1.488	1.470	NS	2.115	2.007	NS
Head	3.28	3.29	3.29	3.27	3.28	3.29	0.012	NS	0.014	0.014	NS	0.021	0.020	NS
Feet	1.29	1.29	1.29	1.29	1.29	1.29	0.001	NS	0.001	0.001	NS	0.001	0.001	NS
Pelt	6.03	6.06	6.04	6.31	6.00	5.90	0.138	NS	0.170	0.169	NS	0.241	0.229	NS
Sum	10.60	10.64	10.62	10.87	10.57	10.47	0.145	NS	0.179	0.177	NS	0.255	0.242	NS
Non-carcass	12.04	12.16	12.10	12.48	11.98	11.79	0.383	NS	0.472	0.466	NS	0.671	0.636	NS
Pluck	2.91	2.93	2.93	2.79	2.93	2.95	0.043	NS	0.053	0.052	NS	0.075	0.071	NS
Liver	1.30	1.31	1.31	1.24	1.31	1.32	0.023	NS	0.023	0.028	NS	0.040	0.038	NS
Spleen	0.13	0.13	0.13	0.13	0.13	0.13	0.001	NS	0.001	0.001	NS	0.001	0.001	NS
Kidneys	0.10	0.10	0.10	0.10	0.10	0.10	0.002	NS	0.002	0.002	NS	0.003	0.003	NS
Kidney fat	0.49	0.50	0.49	0.61	0.47	0.43	0.066	NS	0.081	0.080	NS	0.115	0.109	NS
Gastro-intestinal tract	19.26	19.53	19.48	18.47	19.35	19.44	0.586	NS	0.723	0.715	NS	1.028	0.975	NS
Gastro-intestinal contents	10.91	11.12	11.10	9.64	11.06	11.34	0.469	NS	0.578	0.572	NS	0.822	0.780	NS
Empty gastro-intestinal tract	8.34	8.42	8.38	8.83	8.28	8.10	0.293	NS	0.361	0.357	NS	0.513	0.487	NS
Uterus	0.11	0.11	0.11	0.11	0.11	0.12	0.001	NS	0.002	0.002	NS	0.002	0.002	NS

Table 8.7 Estimation of initial concentration of constituents of ewes slaughtered at term from liveweight and condition score.

Pre-mating	High			Low			SE of the difference					
Late pregnancy	HEHP	LEHP	LELP	HEHP	LEHP	LELP	Premating		Late Pregnancy		Interaction	
Replicates	10	10	9	10	11	11			Min-rep	Max-min	Max-min	Max-rep
Concentration of constituents g/kg												
Carcass												
Dry matter	498.4	499.2	497.6	533.9.	494.1	482.9	12.95	NS	15.97	15.78 NS	22.70	21.54 NS
Water	501.6	500.8	502.4	466.1	505.9	517.1	12.95	NS	15.97	15.78 NS	22.70	21.54 NS
Ash	107.9	108.9	109.1	95.4	109.4	112.7	3.68	NS	4.54	4.49 NS	6.45	6.12 NS
Determined fat	538.1	537.3	535.1	603.3	530.2	510.8	21.1	NS	26.0	25.7 NS	37.0	35.1 NS
Calculated fat	527.2	528.1	525.5	588.7	519.8	500.7	21.8	NS	26.9	26.5 NS	38.2	36.2 NS
Nitrogen	53.4	53.2	53.5	46.7	54.2	56.3	2.50	NS	3.08	3.05 NS	4.38	4.16 NS
Protein	333.7	332.6	334.5	291.7	338.8	352.1	15.62	NS	19.26	19.03 NS	27.38	25.97 NS
Gross energy MJ/kg	28.66	28.67	28.61	30.14	28.48	28.02	0.52	NS	0.64	0.63 NS	0.91	0.86 NS
Non-Carcass												
Dry matter	379.2	380.4	378.5	419.6	374.3	361.5	15.16	NS	18.69	18.47 NS	26.57	25.21 NS
Water	620.8	619.6	621.5	580.4	625.7	638.5	15.16	NS	18.69	18.47 NS	26.57	25.21 NS
Ash	28.1	26.8	27.2	28.5	28.1	28.7	3.19	NS	3.94	3.89 NS	5.60	5.31 NS
Determined fat	542.4	560.8	555.0	548.6	541.3	529.9	45.7	NS	56.4	55.7 NS	80.2	76.1 NS
Calculated fat	611.3	627.9	622.8	614.4	610.7	601.2	40.7	NS	50.2	49.6 NS	71.4	67.7 NS
Nitrogen	51.8	49.7	50.4	50.8	52.0	53.4	5.39	NS	6.65	6.57 NS	9.45	8.96 NS
Protein	323.8	310.4	314.7	317.4	324.8	333.7	33.7	NS	41.5	41.1 NS	59.1	56.0 NS
Gross energy MJ/kg	31.67	32.00	31.90	31.64	31.66	31.50	0.81	NS	0.99	0.98 NS	1.41	1.34 NS

Table 8.8 Estimated initial weight of constituents of ewes slaughtered at term from liveweight and condition score.

Pre-mating	High			Low			SE of the difference					
Late pregnancy	HEHP	LEHP	LELP	HEHP	LEHP	LELP	Premating		Late Pregnancy		Interaction	
Replicates	10	10	9	10	11	11			Min-rep	Max-min	Max-min	Max-rep
Weight of constituents kg									Min Rep	Max-min		
Carcass												
Dry matter	16.60	16.79	16.65	18.82	16.33	15.55	1.053	NS	1.300	1.284 NS	1.847	1.752 NS
Water	16.00	16.10	16.08	15.77	16.02	16.03	0.235	NS	0.290	0.287 NS	0.413	0.391 NS
Ash	1.71	1.74	1.73	1.73	1.71	1.69	0.079	NS	0.098	0.096 NS	0.139	0.132 NS
Determined fat	9.45	9.56	9.44	11.80	9.17	8.50	0.942	NS	1.162	1.148 NS	1.733	1.652 NS
Calculated fat	9.29	9.42	9.30	11.56	9.01	8.26	0.954	NS	1.177	1.162 NS	1.672	1.586 NS
Nitrogen	0.82	0.83	0.83	0.82	0.82	0.82	0.014	NS	0.017	0.017 NS	0.024	0.023 NS
Protein	5.14	5.18	5.16	5.15	5.14	5.12	0.085	NS	0.105	0.105 NS	0.149	0.141 NS
Gross energy MJ	488	494	489	579	477	446	0.040	NS	0.049	0.049 NS	0.070	0.066 NS
Non-carcass												
Dry matter	4.64	4.70	4.66	5.33	4.56	4.32	0.328	NS	0.404	0.399 NS	0.574	0.545 NS
Water	7.40	7.45	7.44	7.46	7.42	7.47	0.123	NS	0.151	0.150 NS	0.215	0.204 NS
Ash	0.11	0.11	0.11	0.13	0.11	0.11	0.010	NS	0.013	0.013 NS	0.018	0.017 NS
Determined fat	2.77	2.89	2.83	3.23	2.71	2.51	0.395	NS	0.487	0.482 NS	0.693	0.657 NS
Calculated fat	3.06	3.18	3.12	3.55	3.00	2.79	0.389	NS	0.480	0.474 NS	0.682	0.647 NS
Nitrogen	0.21	0.21	0.21	0.24	0.21	0.21	0.015	NS	0.184	0.182 NS	0.262	0.249 NS
Protein	1.33	1.28	1.29	1.47	1.31	1.29	0.093	NS	0.115	0.114 NS	0.164	0.155 NS
Gross energy MJ	152	155	153	174	149	140	13.9	NS	17.2	17.0 NS	24.4	23.2 NS

and condition show that all groups of ewes started from a similar state.

8.3iv Mating group By mating there was an average difference of over 12 kg in liveweight and 0.6 units in condition score between the two pre-mating groups which was highly significant ($p < 0.001$). This is shown in Table 8.9. All other carcass and non-carcass components showed differences at the same level, excepting gastro-intestinal contents, which may have been related to feed available immediately prior to slaughter, and the uterus.

Concentration of chemical constituents showed the same pattern of difference (Table 8.10) with fat and energy levels being higher for the high pre-mating group and ash, nitrogen and protein components of the more constant muscle and bone being higher for the low group.

The weights of chemical constituents (Table 8.11) were higher for dry matter, fat, energy and to a lesser extent for ash, nitrogen and protein. Proportionally the carcass fat of the higher premating group was 0.38 heavier compared with 0.11 for carcass nitrogen.

8.3v Ninety days of gestation group As expected the pattern of differences of carcass and non-carcass components was similar to the mating group. No differences had arisen within treatment groups. In the non-carcass, pluck, liver and the gastro-intestinal tract failed to show significant differences.

The concentration and weight of chemical constituents (Tables 8.13 and 8.14) maintained significant differences in parallel with the trends of the previous slaughter point. Only weight of non carcass ash failed to reach significance, but since

Table 8.9 Liveweight, condition score and estimated weight of components at mating of ewes slaughtered at term.

Pre-mating	High			Low			SE of the difference							
Late pregnancy	HEHP	LEHP	LELP	HEHP	LEHP	LELP	Premating		Late Pregnancy			Interaction		
									Min rep	Max-min		Max-min	Max Rep	
Replicates	10	10	9	10	11	11								
Liveweight	77.70	77.20	76.11	63.90	64.91	65.50	1.747	***	2.155	2.129	NS	3.062	2.905	NS
Condition score	3.05	3.10	3.06	2.50	2.36	2.41	0.100	***	0.123	0.121	NS	0.175	0.166	NS
Weight of component kg														
Carcass	35.25	35.14	34.52	27.39	27.50	27.88	0.977	***	1.204	1.190	NS	1.712	1.624	NS
Head	3.36	3.34	3.32	3.15	3.19	3.20	0.033	***	0.041	0.041	NS	0.059	0.056	NS
Feet	1.27	1.26	1.25	1.16	1.19	1.19	0.017	***	0.021	0.021	NS	0.030	0.028	NS
Pelt	6.61	6.48	6.50	5.53	5.58	5.62	0.134	***	0.165	0.163	NS	0.235	0.223	NS
Sum	11.24	11.18	11.07	9.84	9.96	10.01	0.178	***	0.220	0.217	NS	0.312	0.296	NS
Non carcass	12.27	12.21	12.00	9.58	9.70	9.82	0.335	***	0.414	0.409	NS	0.588	0.558	NS
Pluck	1.84	1.83	1.82	1.63	1.65	1.66	0.027	***	0.033	0.033	NS	0.048	0.045	NS
Liver	1.16	1.16	1.15	1.05	1.05	1.05	0.014	***	0.017	0.017	NS	0.024	0.023	NS
Spleen	0.15	0.15	0.15	0.13	0.13	0.13	0.004	***	0.004	0.004	NS	0.006	0.006	NS
Kidneys	0.21	0.21	0.20	0.17	0.18	0.18	0.005	***	0.006	0.006	NS	0.009	0.009	NS
Kidney fat	0.97	0.94	0.89	0.37	0.44	0.46	0.078	***	0.097	0.096	NS	0.138	0.130	NS
Gastro-intestinal tract	17.93	17.72	17.58	16.13	16.63	16.65	0.316	***	0.390	0.385	NS	0.554	0.526	NS
Gastro-intestinal contents	9.87	9.66	9.66	9.75	10.27	10.21	0.251	NS	0.309	0.305	NS	0.439	0.417	NS
Empty gastro-intestinal tract	7.94	7.92	7.79	6.23	6.25	6.33	0.213	***	0.263	0.259	NS	0.373	0.354	NS
Uterus	0.16	0.15	0.15	0.15	0.16	0.16	0.009	NS	0.011	0.011	NS	0.016	0.015	NS

Table 8.10 Estimated concentration of constituents at mating of ewes slaughtered at term

Pre-mating	High			Low			SE of the difference					
Late pregnancy	HEHP	LEHP	LELP	HEHP	LEHP	LELP	Premating	Late pregnancy		Interaction		
Replicates	10	10	9	10	11	11		Min-rep	Max-min		Max-min	Max rep
Concentration of constituents g/kg												
Carcass												
Dry matter	559.0	560.3	556.4	509.8	505.6	508.6	6.64 ***	8.19	8.09 NS		11.64	11.04 NS
Water	441.0	439.7	443.6	490.2	494.4	491.4	6.64 ***	8.19	8.09 NS		11.64	11.04 NS
Ash	95.0	92.4	94.7	122.6	129.4	127.2	5.00 ***	6.17	6.09 NS		8.76	8.31 NS
Determined fat	599.2	605.5	597.2	496.1	478.3	485.8	16.12 ***	19.89	19.65 NS		28.27	26.82 NS
Calculated fat	588.0	593.9	585.4	482.4	465.6	473.0	16.11 ***	19.87	19.64 NS		28.25	26.80 NS
Nitrogen	45.6	44.9	45.8	51.3	59.2	58.4	1.81 ***	2.23	2.20 NS		3.17	3.01 NS
Protein	284.8	280.6	286.4	358.0	370.1	364.8	11.29 ***	13.93	13.76 NS		19.80	18.78 NS
Gross energy MJ/kg	29.83	29.96	29.77	27.40	27.03	27.20	0.367***	0.452	0.447 NS		0.643	0.610 NS
Non carcass												
Dry matter	470.7	474.9	468.2	386.7	374.5	380.3	12.50 ***	15.42	15.23 NS		21.91	20.79 NS
Water	529.3	525.1	531.8	613.3	625.5	619.7	12.50 ***	15.42	15.23 NS		21.91	20.79 NS
Ash	22.3	21.9	22.9	34.0	35.1	34.4	1.61 ***	1.98	1.96 NS		2.82	2.67 NS
Determined fat	712.8	717.5	706.7	578.1	563.7	572.3	18.77 ***	23.15	22.87 NS		32.90	31.22 NS
Calculated fat	748.6	753.3	743.7	627.5	613.2	621.1	17.18 ***	21.19	20.93 NS		30.11	28.57 NS
Nitrogen	34.4	33.8	35.2	51.0	52.7	51.7	2.30 ***	2.84	2.81 NS		4.04	3.83 NS
Protein	215.1	211.5	219.8	318.6	329.5	322.9	14.39 ***	17.75	17.54 NS		25.23	23.94 NS
Gross energy MJ/kg	34.50	34.60	34.41	32.18	31.88	32.03	0.336***	0.414	0.409 NS		0.589	0.559 NS
Uterus dry matter	209.1	210.4	210.8	214.3	211.2	211.4	1.58 NS	1.95	1.93 NS		2.77	2.63 NS

Table 8.11 Estimated weight of constituents at mating of ewes slaughtered at term

Pre-mating	High			Low			SE of the difference					
Late Pregnancy	HEHP	LEHP	LELP	HEHP	LEHP	LELP	Premating		Late pregnancy		Interaction	
Replicates	10	10	9	10	11	11			Min rep	Max-min	Max-min	Max Rep
Weight of constituents kg												
Carcass												
Dry matter	19.78	19.76	19.31	14.15	14.10	14.39	0.705	***	0.869	0.859 NS	1.235	1.172 NS
Water	15.47	15.39	15.21	13.24	13.40	13.49	0.282	***	0.348	0.344 NS	0.494	0.469 NS
Ash	1.84	1.80	1.78	1.60	1.70	1.70	0.056	*	0.069	0.068 NS	0.098	0.093 NS
Determined fat	11.96	12.05	11.68	7.44	7.15	7.41	0.594	***	0.733	0.724 NS	1.042	0.988 NS
Calculated fat	11.74	11.81	11.45	7.24	6.99	7.24	0.586	***	0.722	0.714 NS	1.027	0.974 NS
Nitrogen	0.89	0.88	0.87	0.77	0.79	0.79	0.018	***	0.022	0.022 NS	0.031	0.029 NS
Protein	5.57	5.51	5.45	4.81	4.94	4.94	0.111	***	0.136	0.135 NS	0.194	0.184 NS
Gross energy MJ	593	594	579	398	391	402	24.8	***	30.6	30.3 NS	43.5	41.3 NS
Non carcass												
Dry matter	5.85	5.86	5.70	3.83	3.76	3.87	0.257	***	0.317	0.313 NS	0.451	0.427 NS
Water	6.42	6.35	6.30	5.76	5.94	5.95	0.116	***	0.143	0.141 NS	0.203	0.193 NS
Ash	0.12	0.12	0.12	0.11	0.11	0.11	0.001	***	0.002	0.002 NS	0.003	0.002 NS
Determined fat	4.25	4.27	4.13	2.43	2.34	2.44	0.235	***	0.290	0.286 NS	0.412	0.391 NS
Calculated fat	4.45	4.47	4.33	2.62	2.51	2.61	0.238	***	0.294	0.291 NS	0.418	0.397 NS
Nitrogen	0.19	0.19	0.19	0.16	0.17	0.17	0.004	***	0.005	0.005 NS	0.007	0.007 NS
Protein	1.21	1.19	1.18	1.19	1.03	1.06	0.025	***	0.031	0.031 NS	0.044	0.042 NS
Gross energy MJ	203	204	198	127	124	128	9.8	***	12.1	11.9 NS	17.2	16.3 NS
Uterus dry matter	345.2	332.3	330.5	320.7	353.0	349.9	0.002	NS	0.002	0.002 NS	0.003	0.003 NS

Table 8.12 Liveweight, condition score and estimated weight of body components at 90 days of gestation of term slaughter group

Premating	High			Low			SE of the difference				
Late pregnancy	HEHP	L EHP	L ELP	HEHP	L EHP	LELP	Premating	Late Pregnancy Min-rep	Late Pregnancy Max-min	Interaction Max-min	Interaction Max-rep
Replicates	10	10	9	10	11	11					
Liveweight	76.95	76.65	74.39	66.65	66.77	66.50	1.740 ***	2.146	2.121NS	3.051	2.894 NS
Condition score	2.95	3.00	2.83	2.45	2.27	2.32	0.096 ***	0.119	0.117NS	0.169	0.160 NS
Weights of compoenents kg											
Carcass	34.76	34.60	33.11	28.03	28.10	27.93	1.14 ***	1.41	1.39 NS	2.00	1.90 NS
Head	3.16	3.17	3.14	3.09	3.07	3.07	0.02 ***	0.015	0.015NS	0.021	0.020 NS
Feet	1.26	1.25	1.24	1.18	1.20	1.19	0.019 **	0.023	0.023NS	0.033	0.031 NS
Pelt	6.36	6.38	6.16	5.52	5.40	5.42	0.130 ***	0.160	0.158NS	0.227	0.216 NS
Sum	10.78	10.80	10.54	9.79	9.67	9.69	0.153 ***	0.189	0.187NS	0.269	0.255 NS
Non-carcass	10.27	10.24	9.76	8.17	8.14	8.10	0.346 ***	0.427	0.422NS	0.607	0.576 NS
Pluck	1.47	1.45	1.43	1.34	1.39	1.37	0.040 NS	0.050	0.049NS	0.071	0.067 NS
Liver	0.81	0.80	0.78	0.72	0.73	0.72	0.017 NS	0.021	0.021NS	0.030	0.029 NS
Spleen	0.12	0.12	0.12	0.10	0.10	0.10	0.002 ***	0.003	0.003NS	0.004	0.004 NS
Kidneys	0.17	0.17	0.17	0.15	0.16	0.16	0.006 *	0.007	0.007NS	0.010	0.010 NS
Kidney fat	0.66	0.65	0.58	0.35	0.37	0.36	0.054 ***	0.066	0.065NS	0.094	0.089 NS
Gastro-intestinal tract	18.14	17.86	17.75	16.63	17.37	17.10	0.529 NS	0.652	0.645NS	0.927	0.880 NS
Gastro-intestinal contents	10.48	10.22	10.56	10.94	11.72	11.48	0.375 *	0.463	0.457NS	0.658	0.624 NS
Empty gastro-intestinal tract	7.09	7.09	6.71	5.51	5.40	5.40	0.248 ***	0.306	0.303NS	0.435	0.413 NS

Table 8.13 Estimated concentration of chemical constituents at 90 days of gestation of ewes slaughtered at term

Pre-mating	High			Low			SE of the difference								
Late pregnancy	HEHP	LEHP	LELP	HEHP	LEHP	LELP	Premating			Late pregnancy			Interaction		
Replicates	10	10	9	10	11	11									
Concentration of constituents g/kg										Min-rep	Max-Min		Max-min	Max-rep	
Carcass															
Dry matter	542.6	543.8	528.0	481.9	475.0	475.8	9.37	***		11.55	11.41	NS	16.42	15.58	NS
Water	457.4	456.2	472.0	518.1	525.0	524.2	9.37	***		11.55	11.41	NS	16.42	15.58	NS
Ash	101.8	100.7	110.4	137.5	143.1	142.1	5.52	***		6.81	6.73	NS	9.68	9.18	NS
Determined fat	602.1	604.2	575.7	492.7	480.0	481.6	16.87	***		20.80	20.55	NS	29.57	28.05	NS
Calculated fat	592.2	591.9	566.3	485.7	480.0	479.4	16.90	***		20.84	20.59	NS	29.63	28.11	NS
Nitrogen	44.5	44.3	47.2	55.8	56.9	56.9	1.76	***		2.17	2.14	NS	3.08	2.92	NS
Protein	278.1	277.2	295.2	349.0	355.9	355.3	10.98	***		13.55	13.38	NS	19.25	18.27	NS
Gross energy MJ/kg	29.83	29.80	29.22	27.32	27.26	27.23	0.409	***		0.505	0.499	NS	0.717	0.681	NS
Non carcass															
Dry matter	482.0	483.5	459.7	389.3	379.4	380.5	14.32	***		17.66	17.45	NS	25.10	23.82	NS
Water	518.0	516.5	540.3	610.7	620.6	619.5	14.32	***		17.66	17.45	NS	25.10	23.82	NS
Ash	16.5	16.0	18.5	24.9	26.7	26.3	1.35	***		1.67	1.65	NS	2.37	2.25	NS
Determined fat	762.2	764.3	733.1	641.3	628.1	629.6	18.67	***		23.03	22.76	NS	32.74	31.06	NS
Calculated fat	797.0	799.9	769.0	680.6	665.0	667.3	17.94	***		22.13	21.86	NS	31.45	29.84	NS
Nitrogen	28.0	27.8	31.8	43.7	45.3	45.2	2.24	***		3.01	2.98	NS	4.28	4.06	NS
Protein	174.8	173.4	198.6	273.4	283.2	282.3	15.27	***		18.84	18.61	NS	26.77	25.40	NS
Gross energy MJ/kg	35.42	35.34	34.74	33.11	32.70	32.78	0.337	***		0.415	0.410	NS	0.590	0.560	NS

Table 8.14 Estimated weight of chemical constituents at 90 days of gestation of ewes slaughtered at term

Premating	High			Low			SE of the difference					
Late pregnancy	HEHP	LEHP	LELP	HEHP	LEHP	LELP	Premating		Late pregnancy		Interaction	
Replicates	10	10	9	10	11	11						
Weight of constituents kg									Min-rep	Max-Min	Max-min	Max-rep
Carcass												
Dry matter	18.95	18.89	17.70	13.82	13.69	13.62	0.833	***	1.028	1.015 NS	1.460	1.386 NS
Water	15.82	15.71	15.42	14.21	14.42	14.31	0.326	***	0.403	0.398 NS	0.572	0.543 NS
Ash	1.88	1.86	1.84	1.74	1.78	1.76	0.039	*	0.049	0.048 NS	0.069	0.065 NS
Determined fat	11.53	11.52	10.50	7.27	7.04	7.01	0.678	***	0.836	0.826 NS	1.188	1.127 NS
Calculated fat	11.33	11.29	10.31	7.13	6.99	6.94	0.679	***	0.838	0.828 NS	1.191	1.130 NS
Nitrogen	0.83	0.82	0.80	0.73	0.73	0.73	0.019	***	0.023	0.023 NS	0.033	0.033 NS
Protein	5.18	5.15	5.02	4.54	4.58	4.55	0.116	***	0.144	0.142 NS	0.204	0.194 NS
Gross energy MJ	567	565	523	387	383	380	0.029	***	0.036	0.036 NS	0.052	0.049 NS
Non carcass												
Dry matter	4.95	4.95	4.55	3.31	3.22	3.21	0.261	***	0.321	0.318 NS	0.457	0.433 NS
Water	5.32	5.29	5.21	4.86	4.93	4.89	0.094	***	0.116	0.115 NS	0.165	0.156 NS
Ash	0.08	0.08	0.08	0.07	0.08	0.08	0.003	NS	0.004	0.004 NS	0.006	0.006 NS
Determined fat	3.68	3.78	3.42	2.28	2.18	2.18	0.236	***	0.292	0.288 NS	0.414	0.393 NS
Calculated fat	3.97	3.98	3.59	2.40	2.29	2.29	0.246	***	0.304	0.300 NS	0.431	0.409 NS
Nitrogen	0.14	0.14	0.13	0.12	0.12	0.12	0.002	***	0.003	0.003 NS	0.004	0.003 NS
Protein	0.85	0.85	0.83	0.78	0.78	0.78	0.013	***	0.016	0.016 NS	0.022	0.021 NS
Gross energy MJ	175	175	160	112	108	108	0.010	***	0.012	0.012 NS	0.017	0.016 NS

this was due to residual digesta in the gastro-intestinal tract little importance is attached to it. There was a high variability associated with non-carcass ash as the coefficient of variation was over 20%.

8.3vi Reproductive components at ninety days of gestation

Weights of components are given in Table 8.15. Intact uterus, fluids and foetal weights are significantly heavier for the high pre-mating group, but no differences are evident in the placenta or cotyledons. For most components the covariates sex and litter size were significant.

The numbers of ovulations, days pregnant and litter size were not significantly different.

Concentrations of chemical constituents (Table 8.16) were not significantly different due to treatment, neither were weights of chemical constituents (Table 8.17) in the foetuses and adnexa. The covariates, litter size and sex were significant for the total foetuses and the adnexa.

8.3vii Term group The liveweight and condition scores of the ewes at 142 days of gestation (term), were significantly different (Table 8.18, $p < 0.001$) due to pre-mating and late pregnancy treatment although there was no interaction. At the same level of late pregnancy treatment there was an average difference of about 8.5 kg due to pre-mating treatment. In each case, the HEHP ewes were heavier than the LEHP which were heavier than the LELP group. The condition scores followed the same pattern as liveweight.

Carcass, pelt and some non carcass components showed similar differences at varying degrees of significance.

The concentration of chemical consitituents (Table 8.19)

Table 8.15 Weight of reproductive components at ninety days of gestation with covariates sex and litter size

Treatments Replicates	H 11	L 11	SE of the difference	Level of significance Prem	Covariate	Coefficie of variation
Weight of components kg						
Intact uterus	4.76	4.17	0.259	*	***	13.4
Empty uterus	0.894	0.813	0.0731	NS	**	19.7
Fluids	1.655	1.415	0.1001	*	***	15.0
Total foetus	1.466	1.214	0.1247	*	**	21.4
Total adnexa	1.625	1.542	0.1051	NS	***	15.3
Total cotyledon	0.520	0.526	0.0490	NS	**	21.6
Total placenta	0.211	0.204	0.0182	NS	***	20.3
Total placenta and cotyledon	0.731	0.729	0.0484	NS	***	15.3
Mean foetus	0.853	0.690	0.0950	NS	NS	28.4
Mean cotyledon	0.295	0.308	0.0272	NS	NS	20.7
Mean placenta	0.120	0.117	0.0109	NS	*	21.2
Mean placenta and cotyledon	0.416	0.425	0.0256	NS	*	14.1
Number of components						
Ovulations	2.27	2.28	0.217	NS	NS	21.9
Days pregnant	91.6	90.6	0.78	NS	NS	2.0
Litter size	1.7	1.8	0.19	NS	-	24.6
Proportion males	0.64	0.91	0.323	NS	-	97.9
Total cotyledons	96.9	108.1	11.06	NS	***	24.5
Mean cotyledons	53.0	63.9	6.96	NS	NS	27.4
Total non-functional cotyledons	45.1	35.5	8.93	NS	NS	51.0

Table 8.16 Concentration of chemical constituents in foetus and adnexa at 90 days of gestation

Treatments Replicates	H 11	L 11	SE of the difference	Level of significance Prem Covariate	Coefficient of variation
Foetus g/kg					
Dry matter	140.4	133.1	5.00	NS NS	8.4
Water	859.6	866.9	5.00	NS NS	1.3
Remainder g/kg DM					
Ash	135.6	128.4	5.00	NS ***	8.7
Determined fat	88.4	82.4	5.48	NS *	14.8
Gross energy MJ/kg DM	21.27	20.98	0.210	NS ***	2.3
Nitrogen	103.4	105.1	1.18	NS NS	2.6
Protein	646.3	656.8	7.39	NS NS	2.6
Adnexa g/kg					
Dry matter	158.1	141.8	10.11	NS NS	15.1
Water	841.9	858.2	10.11	NS NS	2.7
Remainder g/kg DM					
Ash	65.0	67.9	2.65	NS **	8.9
Determined fat	174.0	112.0	41.1	NS NS	64.3
Gross energy MJ/kg DM	23.69	22.79	0.916	NS NS	8.8
Nitrogen	111.7	119.1	5.38	NS NS	10.4
Protein	698.0	744.0	33.6	NS NS	10.4

Table 8.17 Weight of chemical constituents in reproductive components at ninety days of gestation with covariates sex and litter size

Treatments Replicates	H 11	L 11	SE of the difference	Level of significance Prem Covariate		Coefficier of variation
Total foetuses g						
Dry matter	209	163	23.3	NS	*	28.8
Water	1257	1051	101.9	NS	**	20.3
Ash	28.5	21.3	3.06	*	**	28.4
Determined fat	18.9	13.2	3.07	NS	NS	44.0
Nitrogen	21.5	17.2	2.36	NS	*	28.1
Protein	134.4	107.4	14.73	NS	*	28.1
Gross energy MJ	4.43	3.41	0.515	NS	NS	30.3
Mean wt per foetus g						
Dry matter	122.0	92.7	17.92	NS	NS	38.5
Water	731	598	77.3	NS	NS	26.8
Ash	16.3	11.9	2.23	NS	NS	36.6
Determined fat	11.5	7.7	2.70	NS	NS	64.7
Nitrogen	12.6	9.7	1.79	NS	NS	36.9
Protein	78.5	60.8	11.18	NS	NS	36.9
Gross energy MJ	2.61	1.95	0.414	NS	NS	41.8
Total adnexa g						
Dry matter	242.6	216.6	14.16	NS	**	13.8
Water	1348	1331	98.4	NS	***	16.4
Ash	15.91	14.78	1.127	NS	***	16.4
Determined fat	43.1	23.6	10.59	NS	NS	71.0
Nitrogen	26.9	25.8	1.56	NS	***	13.3
Protein	168.1	161.4	9.67	NS	***	13.3
Gross energy MJ	5.75	4.93	0.445	NS	NS	18.7

Table 8.18 Liveweight, condition score, and weight of body components at 142 days of gestation

Premating	High			Low			SE of the difference						
Late pregnancy	HEHP	LEHP	LELP	HEHP	LEHP	LELP	Premating	Late pregnancy			Interaction		
								Min rep	Max-min		Max-min	Max-rep	
Replicates	10	10	9	10	11	11							
Liveweight	86.35	82.75	78.28	78.10	73.32	69.91	1.608 ***	1.983	1.959	***	2.818	2.674	NS
Condition score	2.80	2.80	2.39	2.45	2.27	2.18	0.075 ***	0.092	0.091	**	0.131	0.124	NS
Weight of component kg													
Carcass	33.50	28.00	23.50	23.27	23.67	21.80	0.913 ***	1.126	1.113	**	1.600	1.518	*
Head	3.27	3.33	3.20	3.31	3.20	3.17	0.073 NS	0.090	0.089	NS	0.128	0.122	NS
Feet	1.19	1.19	1.17	1.20	1.17	1.13	0.036 NS	0.045	0.044	NS	0.063	0.060	NS
Pelt	7.29	7.25	6.62	6.38	5.61	5.79	0.270 ***	0.333	0.329	NS	0.474	0.449	NS
Non carcass	10.78	10.34	9.47	9.20	8.58	8.23	0.316 ***	0.390	0.385	*	0.554	0.526	NS
Pluck	1.58	1.48	1.43	1.45	1.30	1.33	0.062 *	0.076	0.075	NS	0.108	0.103	NS
Liver	1.13	1.15	1.01	1.04	1.08	0.90	0.035 **	0.044	0.043	***	0.062	0.059	NS
Spleen	0.16	0.17	0.17	0.14	0.14	0.10	0.013 *	0.016	0.016	NS	0.023	0.022	NS
Kidneys	0.17	0.17	0.15	0.17	0.18	0.14	0.005 NS	0.006	0.006	***	0.009	0.008	NS
Kidney fat	0.71	0.55	0.64	0.39	0.31	0.37	0.063 ***	0.077	0.076	NS	0.110	0.104	NS
Gastro-intestinal tract	15.70	15.66	14.89	15.33	14.58	14.34	0.600 NS	0.740	0.731	NS	1.052	0.998	NS
Gastro-intestinal contents	8.67	8.85	8.72	9.28	9.02	8.96	0.568 NS	0.700	0.692	NS	0.995	0.944	NS
Empty gastro-intestinal tract	7.03	6.82	6.16	6.00	5.56	5.37	0.238 ***	0.294	0.290	NS	0.417	0.396	NS

Table 8.19 Concentration of chemical constituents in ewes slaughtered at 142 days of gestation

Premating	High			Low			SE of the difference								
Late pregnancy	HEHP	LEHP	LELP	HRHP	LEHP	LELP	Premating		Late pregnancy			Interaction			
Replicates	10	10	9	10	11	11			Min rep	Max-min		Max-min	Max rep		
Concentration of constituents g/kg															
Carcass															
Dry matter	480.6	458.6	469.0	432.4	428.8	427.3	8.67	***	10.70	10.57	NS	15.21	14.43	NS	
Water	519.4	541.4	531.0	567.4	571.2	572.7	8.67	***	10.70	10.57	NS	14.21	14.43	NS	
Ash	109.6	112.2	133.7	124.0	147.9	146.1	7.98	**	9.85	9.73	NS	13.99	13.28	NS	
Determined fatg/kgDM	549.8	513.8	509.5	480.6	432.5	448.9	16.71	***	20.60	20.36	NS	29.29	27.28	NS	
Calculated fat	555.9	505.2	505.8	469.5	414.6	434.9	19.12	***	23.59	23.30	NS	33.52	31.89	NS	
Nitrogen	50.5	54.2	53.3	60.4	63.7	58.5	1.92	***	2.37	2.34	NS	3.36	3.19	NS	
Protein	315.5	338.7	333.0	377.2	398.3	365.7	11.20	***	14.79	14.61	NS	21.02	19.94	NS	
Gross energy MJ/kgDM	29.29	27.84	27.74	27.35	25.70	25.72	0.531	***	0.655	0.648	*	0.931	0.884	NS	
Non carcass															
Dry matter	433.4	436.7	411.1	361.9	354.9	371.7	13.08	***	16.13	15.94	NS	22.93	21.75	NS	
Water	566.6	563.3	588.9	638.1	645.1	628.3	13.08	***	16.13	15.94	NS	22.93	21.75	NS	
Ash	22.7	21.5	23.0	27.9	25.2	27.0	1.76	*	2.17	2.14	NS	3.08	2.92	NS	
Determined fatg/kgDM	654.7	659.9	660.3	567.6	541.1	591.6	22.7	***	28.1	27.7	NS	39.9	37.8	NS	
Calculated fat	679.4	708.1	706.8	623.1	592.4	640.3	21.0	***	25.9	25.6	NS	36.9	35.0	NS	
Nitrogen	45.6	41.5	41.2	51.1	56.1	48.5	2.74	**	3.38	3.34	NS	4.80	4.56	NS	
Protein	285.2	259.6	257.5	319.3	350.8	303.3	17.1	**	21.1	20.9	NS	30.0	28.4	NS	
Gross energy MJ/kgDM	33.43	33.95	33.85	29.02	31.56	32.32	0.996	**	1.228	1.213	NS	1.745	1.656	NS	

were significantly different in both carcass and non carcass due to pre-mating, but not to late pregnancy treatment. Dry matter, fat and energy were at a higher concentration in the ewes on high pre-mating treatment, while water, ash, nitrogen and protein were at a higher concentration on the low pre-mating treatment.

The weights of chemical constituents (Tables 8.20 and 8.21) in the carcass were generally heavier for the high pre-mating treatment and nitrogen, protein and energy were also affected by late pregnancy treatment. Little difference was apparent between the HEHP and LEHP groups, but there was about 1 kg less nitrogen in the carcasses of LELP groups. The non-carcass weights of chemical constituents differed in the same way.

8.3viii Term group - reproductive components Total and mean weight of foetuses (Table 8.22) were significantly affected by late pregnancy treatment ($p < 0.01$ and $p < 0.001$ respectively). None of the other weights were significantly affected by treatment, although covariate effects were significant. The empty uterus weight was also significantly affected by late pregnancy treatment. The greatest differences were evident between the high and low protein treatments, with litte difference due to energy.

Concentration of chemical constituents in the adnexa were not significantly different, but weights of chemical constituents were influenced by protein level in late pregnancy (Table 8.23).

Table 8.20 Weight of chemical constituents of ewes slaughtered at term

Premating	High			Low			SE of the difference								
Late pregnancy	HEHP	LEHP	LELP	HEHP	LEHP	LELP	Premating		Late pregnancy			Interaction		CV%	
Replicates	10	10	9	10	11	11			Min rep		Max-min	Max-min		Max-rep	
Weight of constituents kg															
Carcass															
Dry matter	14.3	13.2	12.3	11.1	10.6	9.6	0.61	***	0.75	0.74	NS	1.07	1.01	NS	20.2
Water	15.4	15.6	13.5	14.3	13.9	12.8	0.44	**	0.54	0.54	**	0.77	0.73	NS	12.6
Ash	1.6	1.4	1.6	1.3	1.5	1.4	0.81	NS	1.0	1.0	NS	1.4	1.3	NS	21.6
Determined fat	8.0	6.8	6.5	5.5	4.8	4.4	0.47	***	0.58	0.57	NS	0.82	0.78	NS	30.9
Calculated fat	8.1	6.6	6.4	5.4	4.5	4.3	0.47	***	0.58	0.58	NS	0.83	0.79	NS	31.7
Nitrogen	0.72	0.70	0.62	0.65	0.66	0.55	0.022	**	0.028	0.027	**	0.039	0.037	NS	13.4
Protein	4.50	4.40	3.90	4.60	4.10	3.44	0.140	**	0.172	0.170	**	0.245	0.232	NS	13.4
Gross energy MJ	424	363	344	307	275	250	20.9	***	25.8	25.5	*	36.6	34.8	NS	25.1
Non carcass wt kg	10.8	10.3	9.5	9.2	8.6	8.2	0.32	***	0.39	0.39	*	0.55	0.53	NS	13.1
Dry matter	4.7	4.5	3.9	3.4	3.1	3.1	0.23	***	0.29	0.28	NS	0.41	0.38	NS	24.0
Water	6.0	5.8	5.6	5.9	5.5	5.1	0.14	*	0.17	0.17	**	0.24	0.23	NS	9.5
Ash	1.0	1.0	0.9	0.9	0.7	0.8	0.34	***	0.42	0.41	*	0.60	0.57	*	15.3
Determined fat	3.2	3.0	2.6	2.0	1.8	1.9	0.22	***	0.27	0.26	NS	0.38	0.36	NS	35.3
Calculated fat	3.3	3.2	2.8	2.1	1.9	2.0	0.22	***	0.27	0.26	NS	0.38	0.36	NS	33.2
Nitrogen	0.20	0.19	0.15	0.16	0.16	0.15	0.064	***	0.079	0.078	***	0.011	0.011	NS	14.9
Protein	1.27	1.17	0.96	1.02	1.00	0.91	0.402	***	0.495	0.490	***	0.704	0.668	NS	14.9
Gross energy MJ	160	154	133	98	99	101	9.5	***	11.7	11.6	NS	16.7	15.8	NS	30.1

Table 8.21 Weight of chemical constituents of ewes slaughtered at term. Ewe body carcass and non carcass.

Premating	High			Low			SE of the difference						CV%
Late pregnancy	HEHP	LEHP	LELP	HEHP	LEHP	LELP	Premating	Late pregnancy		Interaction			
Replicates	10	10	9	10	11	11		Min rep	Max-min		Max-min	Max rep	
Weight of constituents kg													
Dry matter	19.38	17.81	16.31	14.40	13.67	12.72	0.813 ***	1.002	0.990 NS		1.425	1.351 NS	20.3
Water	21.56	21.49	19.21	20.16	19.32	17.88	0.536 ***	0.661	0.653		0.940	0.892 NS	10.5
Ash	1.70	1.54	1.51	1.41	1.58	1.44	0.079 NS	0.097	0.096 NS		0.138	0.131 NS	20.1
Determined fat	11.33	9.77	9.10	7.41	6.58	6.30	0.675 ***	0.833	0.823 NS		1.184	1.123 NS	31.6
Calculated fat	11.45	9.81	9.26	7.51	6.56	6.32	0.678 ***	0.836	0.826 NS		1.189	1.128 NS	31.5
Nitrogen	0.933	0.891	0.777	0.814	0.821	0.696	0.0263***	0.324	0.320 ***		0.460	0.437 NS	12.5
Protein	5.834	5.517	4.855	5.088	5.134	4.347	0.1641***	2.024	2.000 ***		2.877	2.730 NS	12.5
Gross energy	588	517	478	405	379	351	28.6 ***	35.3	34.9 NS		50.2	47.6 NS	24.8

Table 8.22 Weight of products of conception of term group ewes with covariates sex and litter size

Pre-mating	High			Low			SE of the difference							Cov sig	Coeff. Varn.%
Late Pregnancy	HEHP	LEHP	LELP	HEHP	LEHP	LELP	Premating		Late Pregnancy			Interaction			
									Min-rep	Max-Min		Max-Min	Max-rep		
Replicates	10	10	9	10	11	11									
Weights kg															
Udder weight	1.73	1.52	1.45	1.65	1.42	1.35	0.106	NS	0.129	0.127	NS	0.182	0.173	NS	26.1
Empty uterus	1.40	1.40	1.20	1.40	1.38	1.11	0.063	NS	0.077	0.076	**	0.109	0.103	NS	**	17.9
Total foetuses	9.46	9.68	7.56	8.94	8.91	7.65	0.382	NS	0.459	0.454	**	0.654	0.621	NS	***	16.2
Total placenta	0.493	0.436	0.464	0.477	0.489	0.416	0.0268	NS	0.0325	0.0321	NS	0.0461	0.0431	NS	***	21.6
Total cotyledons	0.604	0.569	0.502	0.610	0.568	0.504	0.0336	NS	0.0409	0.404	NS	0.0579	0.0549	NS	***	22.4
Total placenta and cotyledons	1.097	1.006	0.966	1.087	1.057	0.920	0.0532	NS	0.0646	0.0639	NS	0.0916	0.0869	NS	***	19.4
Mean foetus	4.971	5.078	4.315	4.807	4.841	4.100	0.1709	NS	0.2054	0.2029	***	0.2924	0.2774	NS	***	13.5
Mean placenta	0.261	0.237	0.266	0.254	0.267	0.221	0.0150	NS	0.0183	0.0181	NS	0.0259	0.0246	NS	***	22.4
Mean cotyledon	0.315	0.298	0.277	0.320	0.305	0.226	0.0182	NS	0.0221	0.0219	NS	0.0314	0.0298	NS	NS	22.9
Mean cotyledon and placenta	0.576	0.534	0.543	0.574	0.574	0.571	0.486	NS	0.0358	0.0353	NS	0.0507	0.0481	NS	***	20.1
Numbers															
Days pregnant	142	142	142	142	142	142	0.2	NS	0.2	0.2	NS	0.3	0.3	NS	NS	0.4
Ovulations	1.9	2.1	2.2	2.4	2.1	2.1	0.2	NS	0.2	0.2	NS	0.3	0.3	NS	*	26.8
Total cotyledons	121.6	107.2	117.1	113.4	114.4	118.3	5.04	NS	6.13	6.05	NS	8.68	8.24	NS	***	16.3
Mean cotyledons/foetus	65.1	55.8	62.9	59.2	62.4	63.7	3.07	NS	3.72	3.68	NS	5.28	5.01	NS	**	18.6
Total nonfunctional cotyledons	35.9	39.6	57.0	40.9	50.4	45.5	4.22	NS	5.13	5.07	NS	7.28	6.90	NS	***	35.2
Mean nonfunctional cotyledons	22.6	23.2	38.7	24.1	31.9	26.6	3.40	NS	4.13	4.08	NS	5.85	5.55	*	***	45.8

Table 8.23 The concentration and weight of chemical constituents in the adnexa at term

Pre-mating	HIGH			LOW			SE of the difference							Cov Sig	Coefficient of Variation %
Late pregnancy	HEHP	LEHP	LELP	HEHP	LEHP	LELP	Premating	Late pregnancy			Interaction				
								Min-Rep	Max-Min		Max-Min	Max-Rep			
Replicates	10	10	9	10	11	11									
Concentration g/kg															
Dry matter	151.0	150.5	137.7	150.7	149.0	1458	2.85	NS	3.46	3.42	*	4.91	4.66	NS	NS	7.2
Water	849.0	849.5	862.3	849.3	851.0	8542	2.85	NS	3.46	3.42	*	4.91	4.66	NS	NS	1.2
Remainder g/kg DM															
Ash	63.6	61.1	62.2	62.0	66.8	646	1.52	NS	1.84	1.82	NS	2.61	2.48	NS	NS	8.9
Determined fat	44.1	57.6	42.3	69.2	39.8	571	9.72	NS	11.81	11.67	NS	16.75	15.89	NS	NS	70.2
Nitrogen	131.9	131.2	130.1	128.8	132.1	1292	1.57	NS	1.91	1.89	NS	2.71	2.57	NS	NS	4.5
Protein	82.4	82.0	81.3	80.5	82.6	808	0.98	NS	1.19	1.18	NS	1.69	1.61	NS	NS	4.5
Gross energy MJ/kg DM	21.6	21.5	21.2	22.0	21.2	21.6	0.21	NS	0.25	0.25	NS	0.36	0.34	NS	NS	3.6
Weight g															
Total adnexa	2500	2410	2170	2490	2440	2050	94	NS	115	114	**	162	154	NS	**	15.0
Dry matter	376	364	294	372	364	230	14.3	NS	17.6	17.4	***	24.8	23.5	NS	***	15.5
Water	2124	2050	1873	2119	2080	1746	81.0	NS	100.0	98.8	**	140.7	133.5	NS	***	15.2
Ash	24	22	18	23	24	19	1.0	NS	1.3	1.3	***	1.8	1.7	NS	***	17.8
Determined fat	16	21	12	24	15	20	3.6	NS	4.4	4.4	NS	6.2	5.9	NS	NS	74.4
Nitrogen	50	48	48	48	48	38	1.9	NS	2.3	2.3	***	3.2	3.0	NS	***	15.5
Protein (N x 6.5)	310	299	239	301	300	240	11.6	NS	14.4	14.2	***	20.2	19.2	NS	***	15.5
Gross energy MJ	8.2	7.8	6.2	8.2	7.7	65	0.34	NS	0.41	0.41	***	0.58	0.55	NS	***	16.9

8.4 Discussion

8.4i Liveweight and Condition Score The liveweight of the ewes followed the pattern planned (Figure 8.2). The two groups divided quite distinctly by mating, and more or less maintained their weight through to ninety days of gestation. The low group rose slightly during this period. Weights diverged again due to late pregnancy treatment, the high LELP and the low HEHP converging. All ewes gained weight during late pregnancy. The condition score of the ewes followed the same pattern initially, but tended to fall gradually from mating onwards. The weight gain was therefore likely to be due to the products of conception.

8.4ii Carcass and Non-Carcass The carcass and non-carcass weights (Figure 8.3) divided initially as did liveweight, but thereafter showed a decline. The ewes' bodies actually lost weight at some point during early and mid pregnancy, and further declined in late pregnancy, with the exception of the high HEHP group. Latterly, the non carcass components maintained their weight, while the drop in the total ewe body was mainly accounted for by the carcass. This adds weight to the evidence that a ewe may be maintaining or gaining overall weight during pregnancy, but is actually losing weight from her own body components.

8.4iii Concentration of chemical constituents The changes in dry matter, fat and energy appear to be inversely related to changes in water, ash, nitrogen and protein. Ash, nitrogen and protein are components of structural parts of the body, that is bone and muscle. Water forms a high proportion of

Figure 8.2 Liveweight and condition score throughout the experimental period.

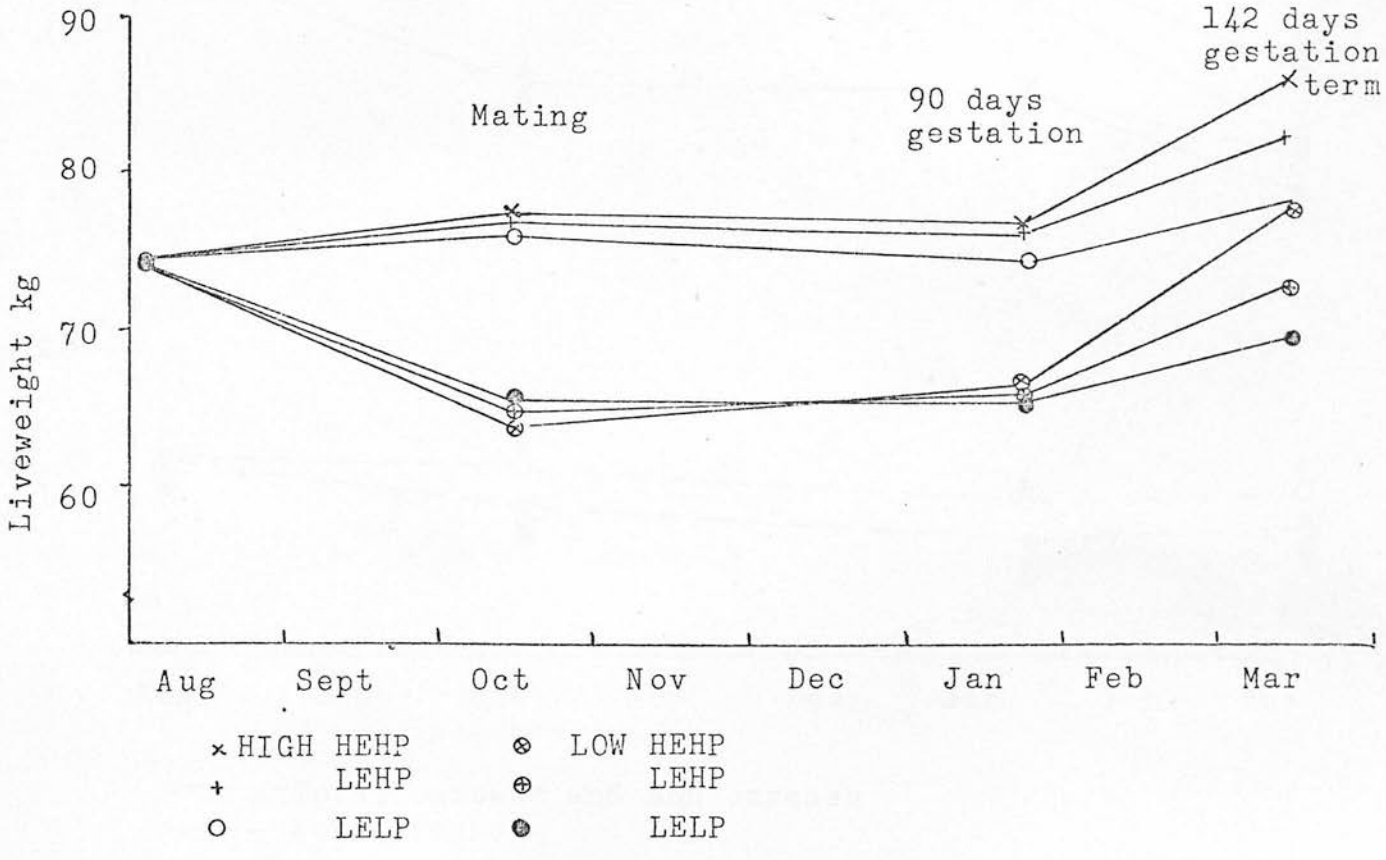
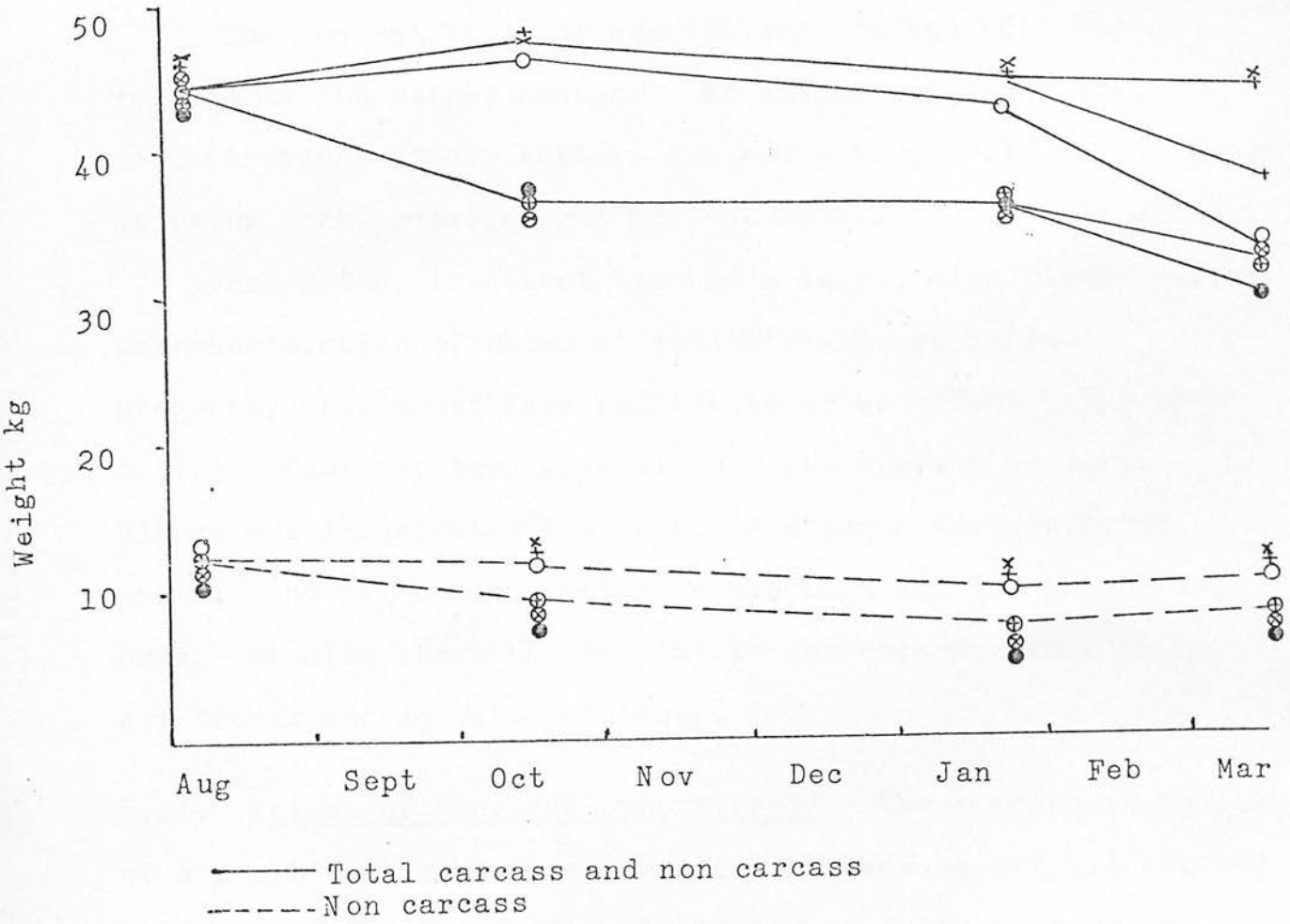


Figure 8.3 Non carcass + carcass weight



Treatment symbols as before

of lean tissue and is therefore parallel in concentration to protein. These functional parts are likely to be maintained at the expense of storage tissue, such as adipose.

It follows, therefore, that as an animal loses fat, the bone and muscle components form a larger proportion of the total body.

Energy is concentrated in the form of fat and there is little water associated with it in adipose tissue. The fatter an animal becomes the higher the dry matter and the energy.

The concentration of constituents in the ewes was related to the weight changes. As weight was lost, the concentrations of dry matter, fat and energy fell, while those of water, ash, nitrogen and protein increased and vice versa.

Pre-mating treatment has had a large, significant effect on concentration of chemical constituents, while late pregnancy treatments have had little or no effect. The pre-mating effect has been maintained right through to term. Figure 8.4 illustrates the opposite effects on effects on protein and fat concentration in the high and low pre-mating ewes. It also shows the decline in fat concentration on all treatments in late pregnancy.

8.4iv Weight of chemical constituents The changes in weight of dry matter and water content of the carcass are illustrated in Figure 8.6. The total weight changes follow a similar pattern to liveweight in the first two stages, but in late pregnancy, weight is lost. The increase in liveweight is due to the growing reproductive components.

Figure 8.7 illustrates the constancy and lack of variation in protein content of the carcass. Nevertheless, protein is lost in late pregnancy which suggests that, even supposedly

Figure 8.4 Fat and protein concentration changes in the carcass

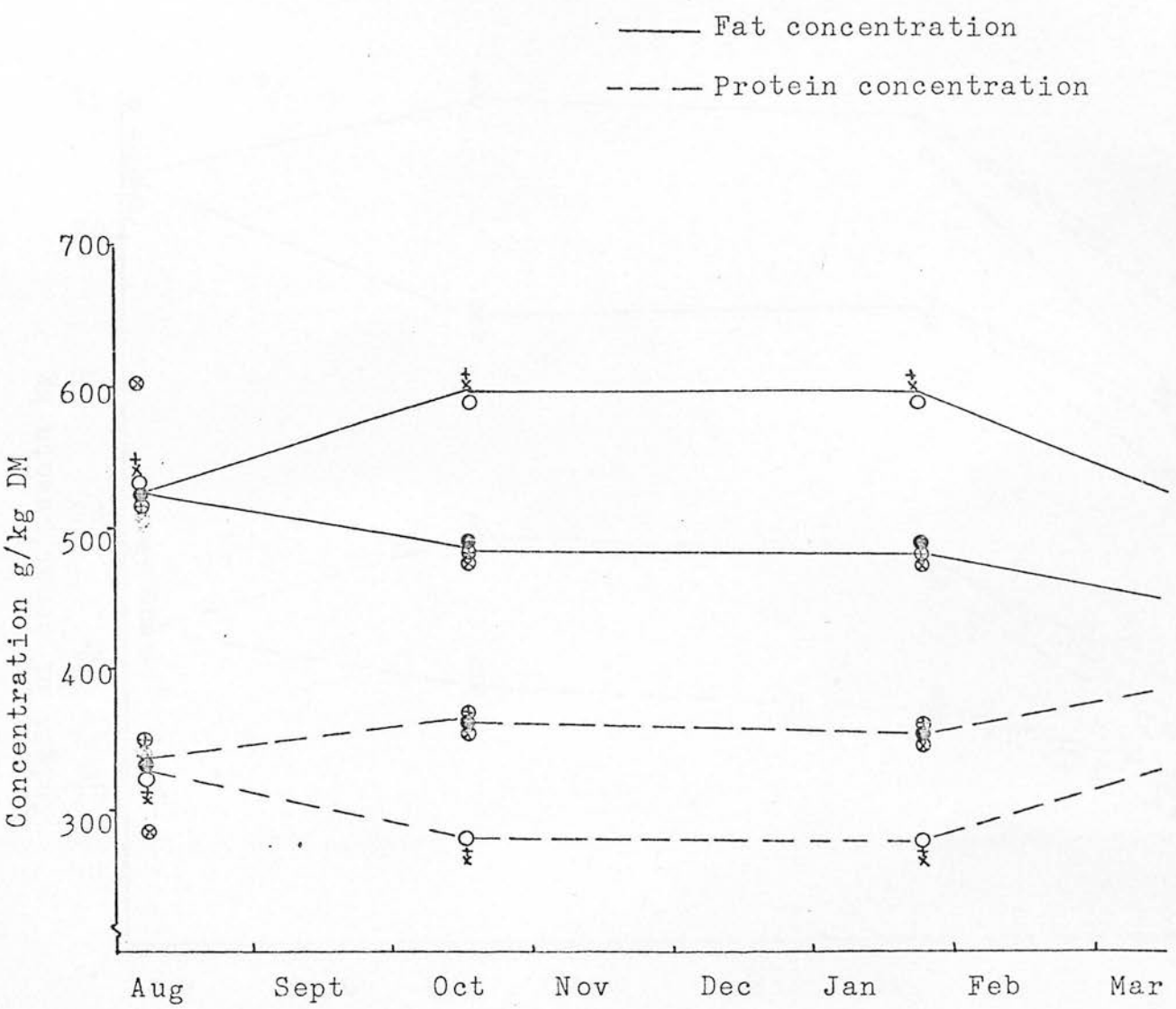


Figure 8.5 Dry matter and water content of the carcass

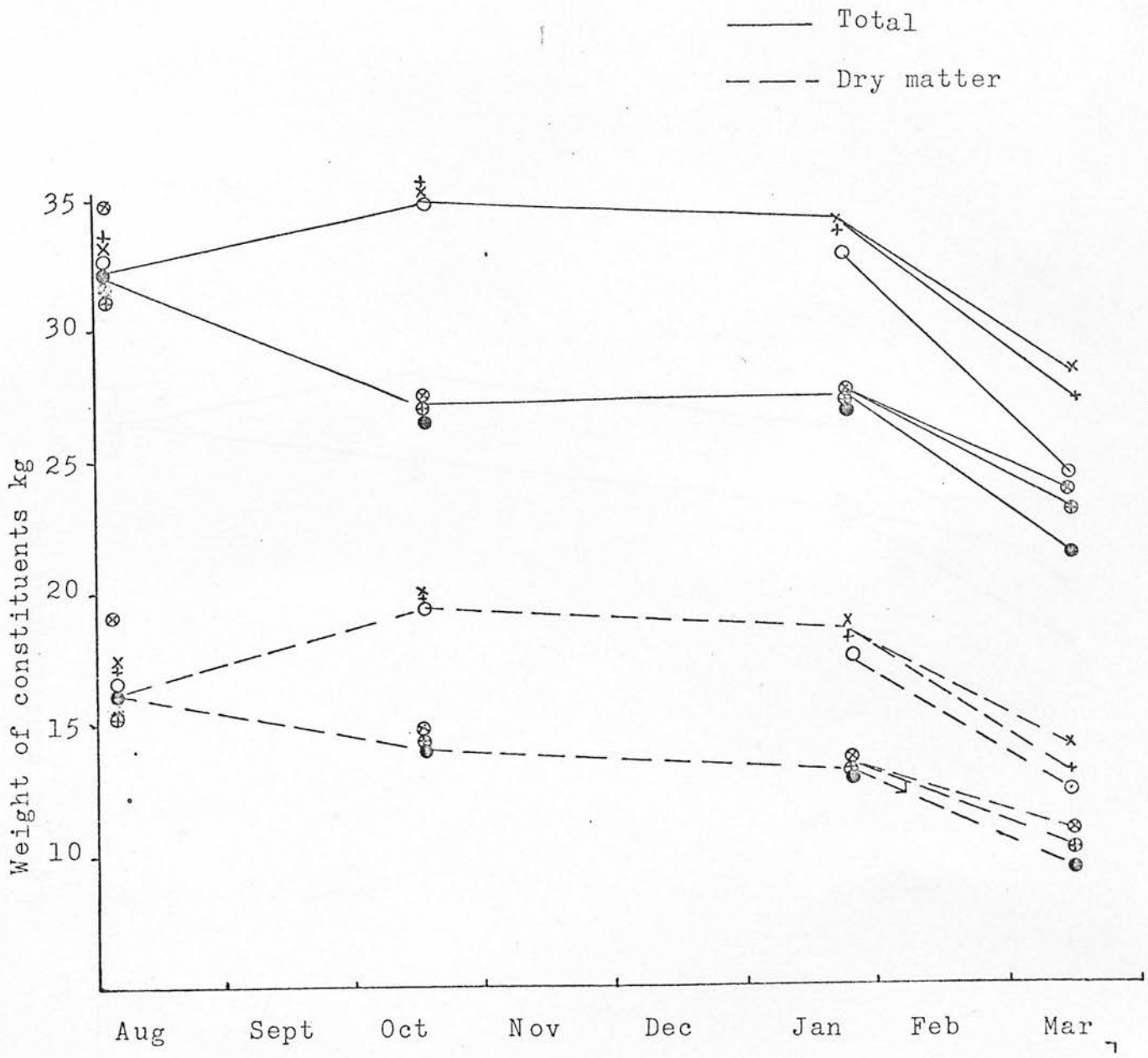


Figure 8.6 Protein content of the carcass

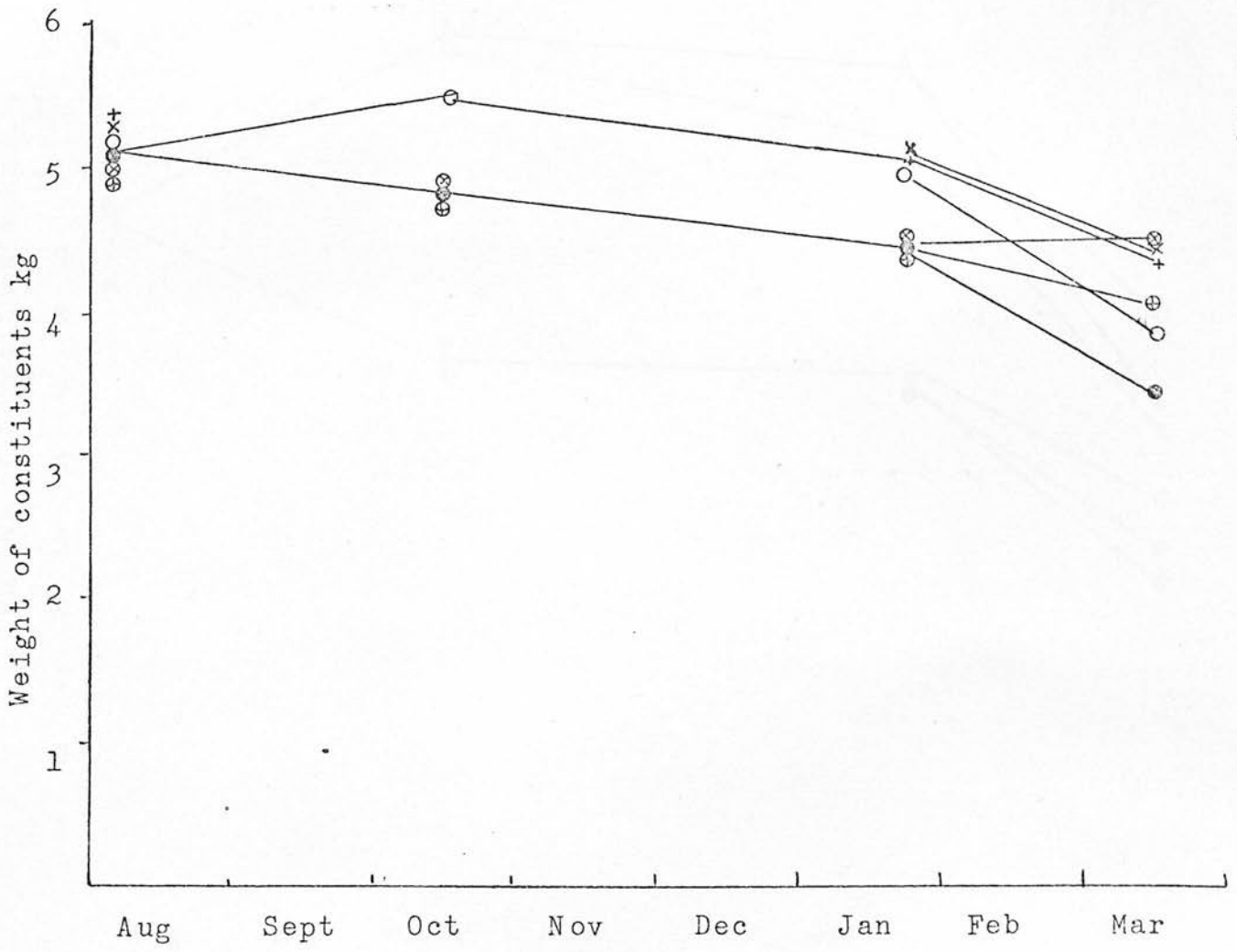


Figure 8.6 Protein content of the carcass

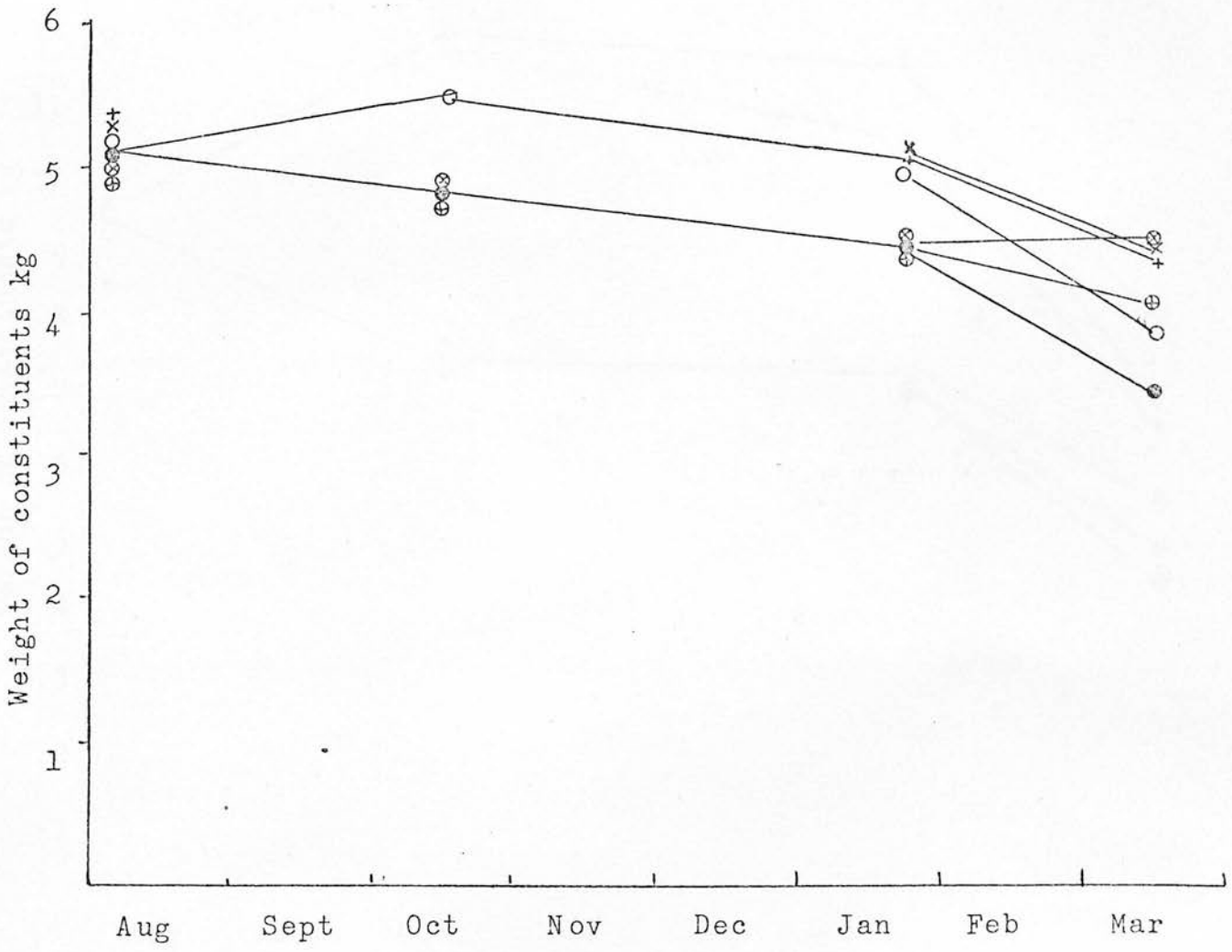
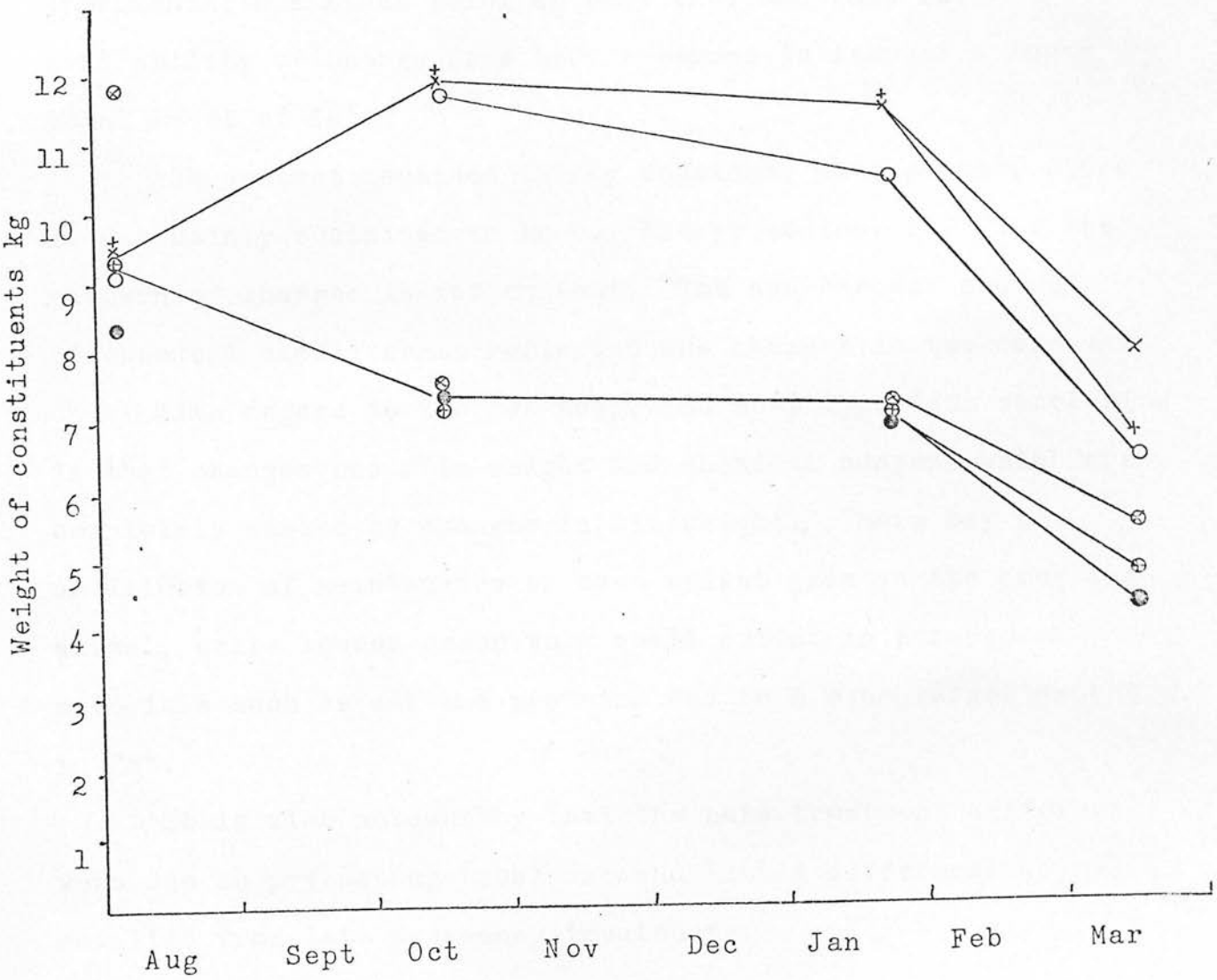


Figure 8.7 Fat content of the carcass



adequately-fed ewes, were in deficient nutritional status and that reserves were being withdrawn.

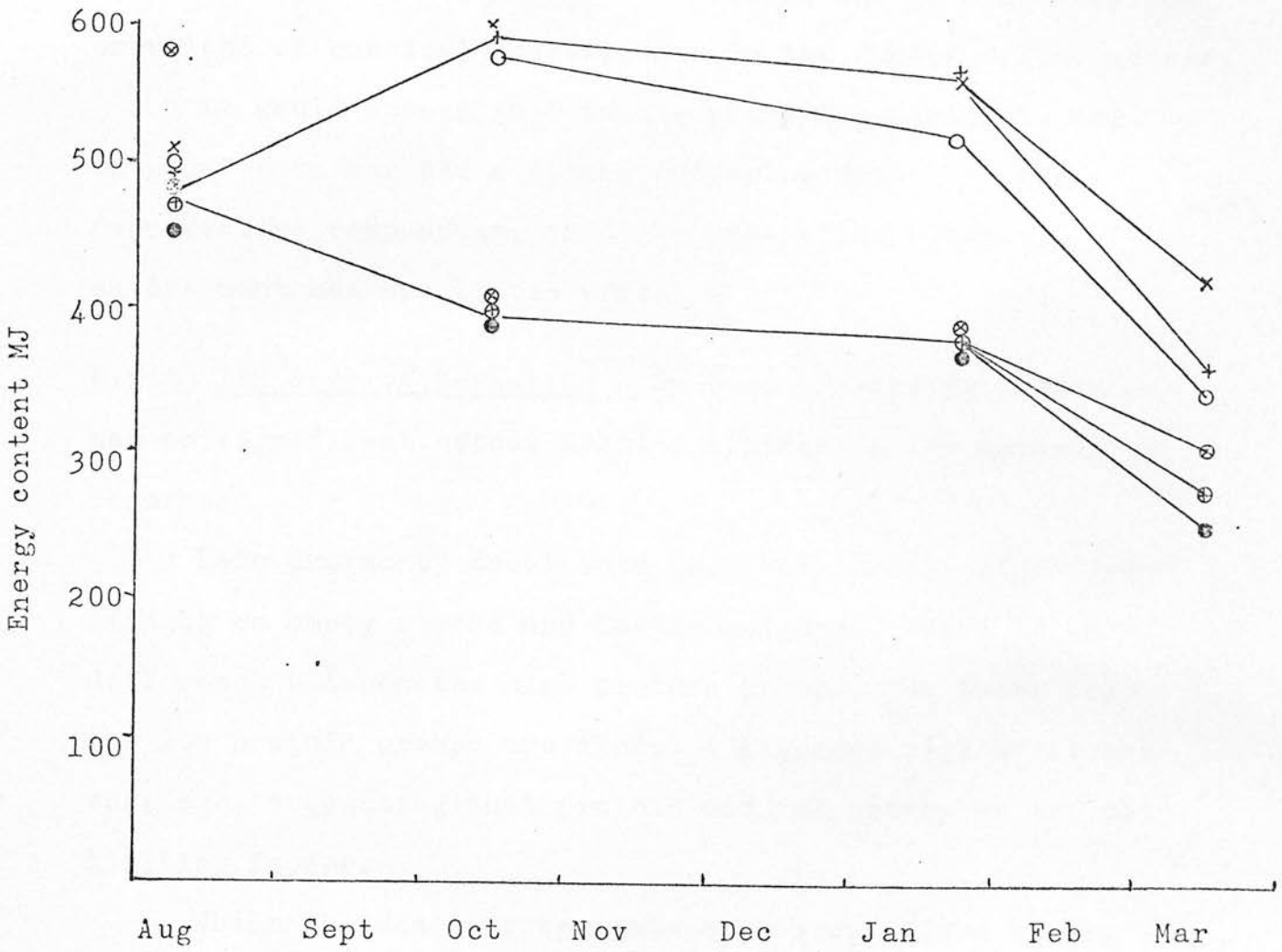
The fat content (Figure 8.7) presents a much more variable picture, in that initial fat content is quite variable. All ewes lost fat in late pregnancy. Surprisingly the high pre-mating ewes seemed to lose more fat. It is possible that the low pre-mating ewes lost less fat because they were approaching a minimum level of body fat, and that the availability of energy from body reserves is less at a lower total level of fat.

Ash content remained fairly constant, as expected, since it was mainly contained in bone. Energy content followed the pattern of changes in fat content. The non-carcass content of chemical constituents reflected the changes in the carcass.

With regard to the ewe body, the most important conclusion is that changes occur in weight and chemical content which are completely masked by changes in liveweight. There may be an illusion of maintenance or even weight gain in the pregnant animal, while losses occur to a small extent in structural materials such as ash and protein, and to a much larger extent in fat.

It is also noteworthy that the main treatment differences were due to pre-mating treatment and little difference resulted from late pregnancy treatments.

Figure 8.8 Energy content of the carcass



8.5 Reproductive Components

8.5i Ninety Days of Gestation The maternal body has a large buffering effect on foetal components, and in this experiment only a slight effect of pre-mating treatment is evident in the intact uterus, fluids and total foetal weight at ninety days of gestation. The combined covariates sex and litter size have had a significant effect on most variates.

As expected, there were no differences in concentration or weight of chemical constituents in the foetus or the adnexa.

It would appear that in the present experiment, the maternal body has had a strong buffering effect on the reproductive components, and that pre-mating external environment has had little effect.

8.5ii 142 days of Gestation By term pre-mating treatment has no significant effect despite limitations on maternal reserves.

Late pregnancy treatments have had clearly significant effects on empty uterus and foetus weights. There is no difference between the high protein groups, but lambs from the low protein groups are almost a kilogramme lighter at the same age, suggesting that protein and not energy is the main limiting factor.

While the adnexa components have grown since ninety days of gestation, contrary to expectation they do not appear to have been influenced by nutritional treatments. The total adnexa weight difference was significant due to the inclusion of the empty uterus and the sum of trends. While there were no significant concentration differences, the weights of

chemical constituents in the adnexa were significantly different. Again the major differences were between the high and low protein treatments, with little difference due to energy.

The composition of the lambs is not known as they were reared, but implications about weight and fat content in relation to viability may be made in the context of other work. This is discussed in the general discussion.

8.6 Conclusions

The main effect of pre-mating treatment has been on ewe weight and body composition. The differences have remained throughout pregnancy. The treatment before mating has not significantly affected placenta and cotyledon development.

Foetal growth has been influenced by nutrition during late pregnancy. A high protein concentration has allowed energy to be used more efficiently when dietary energy resources were low. There was no carry-over effect on foetal growth from pre-mating treatment.

CHAPTER 9

EXPERIMENT 3

9.1 Introduction

In the previous experiment an increase in lamb birth weight was obtained as a result of the inclusion of fishmeal in the ewe's diet. A further experiment was undertaken to define the optimum level of fishmeal in the diet and to study subsequent effects on milk yield and lamb growth rate. Concentrate levels of up to 1.4 kg/ewe/day were offered in the last experiment, to achieve energy and protein intakes recommended while normally up to 0.65 kg/ewe/day would be offered in commercial practice. This experiment used more commercial levels of concentrates.

9.2 Materials and Methods

9.2i Animals The mating dates of a flock of Scottish Halfbred ewes were recorded daily to identify ewes which conceived to the first service. At around 90 days of gestation 46 twin-bearing ewes were identified by X-ray photography from a group of 84. These were allocated at random to treatments. Ewes were housed, penned individually as in previous experiments and were bedded on wood shavings. At lambing six ewes were discarded, leaving forty to continue on the treatments into lactation.

9.2ii Diets and Treatments The four treatments were concentrates made up of different constituents. They were made by substituting 0, 0.05, 0.15 and 0.20 white fishmeal for whole barley in a pellet which also contained 0.10 molasses, vitamins

and minerals. The analyses of the four diets can be found in Table 9.1. Treatments will be referred to as 1, 2, 3 and 4 corresponding to 0, 0,05, 0.15 and 0.20 fishmeal.

Before lambing, hay, of quality given in Table 9.1, was offered ad libitum and concentrate level started at 150 g/ewe/day, rose by 100 g each week until it reached 650 g/ewe/day, two weeks before lambing. After lambing hay was restricted to 400 g/ewe/day and swedes were offered ad libitum. The analysis of the swedes is given in Table 9.1.

At the end of the trial concentrates in lactation were gradually reduced from 650 g/d to 0 with a 0.10 fishmeal level and ewes were turned out to pasture.

9.2iii Measurements Ewes were weighed and condition scored at a standard time each week. Intakes of hay and swedes were recorded when they were offered ad libitum. Refusals were collected, weighed and analysed.

At birth, lambs were weighed wet, towel and blow dried, re-weighed, allowed to suckle and weighed again. Lambs were allowed to suckle at four hourly intervals during the first 24 hours of life and were weighed before and after suckling to measure colostrum yield.

During one day each week for four weeks, lambs were removed from their dams for a two hour pre-recording period and suckled to empty the ewes' udders by a standard amount for the start of the 24 hour recording. Thereafter lambs were allowed access to the ewes every 4 hours and were weighed before and after suckling. Lambs were observed carefully during this time so that weighings took place before losses occurred due to urination or defaecation.At the end of the 24 hour period

Table 9.1 Composition of feeds used in late pregnancy and lactation.

Constituent	Concentrate				Hay	Swedes
	1	2	3	4		
Determined values						
Dry matter g/kg	874	881	890	889	854	111
Values in dry matter						
Crude protein g/kg	107	134	193	220	85	73
Fibre g/kg	50	39	39	43	360*	93
Ash g/kg	63	69	91	93	63	66
Derived values						
Digestible crude protein g/kg	85	107	154	176	41	61
Metabolisable energy MJ/kg	13.0	13.0	12.8	12.6	9.0	12.8

* Modified Acid Detergent Fibre
the rest T fibre

the lambs were removed for a further 2 hours after which ewes received an intramuscular injection of ½ ml oxytocin (Leo Laboratories Ltd) and a milk sample was collected for analysis.

9.2iv Statistical Analysis To calculate nutrient intakes, the intake of a particular nutrient from different dietary components was calculated on a daily basis and added together to give daily nutrient intake. Daily intakes of all ewes were aligned to correspond with the same day before, or day after lambing.

Lambs weights were calculated as the mean of the six pre-suckling weights each week.

The Genstat Statistical Package (Lawes Agricultural Trust, 1980) was used to analyse the results.

9.3 Results

9.3i Ewe liveweight and condition score The liveweights and conditions of the ewes given in Table 9.2 show that at no time were ewe weights significantly different. Figure 9.1 shows the expected rise in liveweight up to lambing time, sharp drop and subsequent fall after lambing. It also shows a trend for ewes on the 0.15 and 0.20 fishmeal to lose less weight albeit statistically insignificant.

9.3ii Feed intakes Table 9.3a gives nutrient intakes in the seven weeks up till lambing. Crude protein intake is significantly different throughout as expected with the different concentrations in the concentrate. There was also a trend for dry matter and metabolisable energy intake to increase as the protein concentration increased. This became significant in the period 1 to 2 weeks before lambing.

Table 9.2 Ewe liveweight and condition score

Treatment	Mating 23.10.80		8 wks prelambing		After 4 weeks Lactation	
	LW kg	C.S.	LW kg	C.S.	LW kg	C.S.
1	80.8	3.2	80.7	3.3	65.7	2.5
2	77.3	3.0	77.7	3.2	66.7	2.5
3	79.1	3.0	76.9	3.2	70.0	2.6
4	78.1	3.0	80.2	3.0	71.7	2.7
SE of the differemce	3.61 NS	0.27 NS	3.57 NS	0.15 NS	3.80 NS	0.2 NS

Figure 9.1 Ewe liveweight change during the experiment

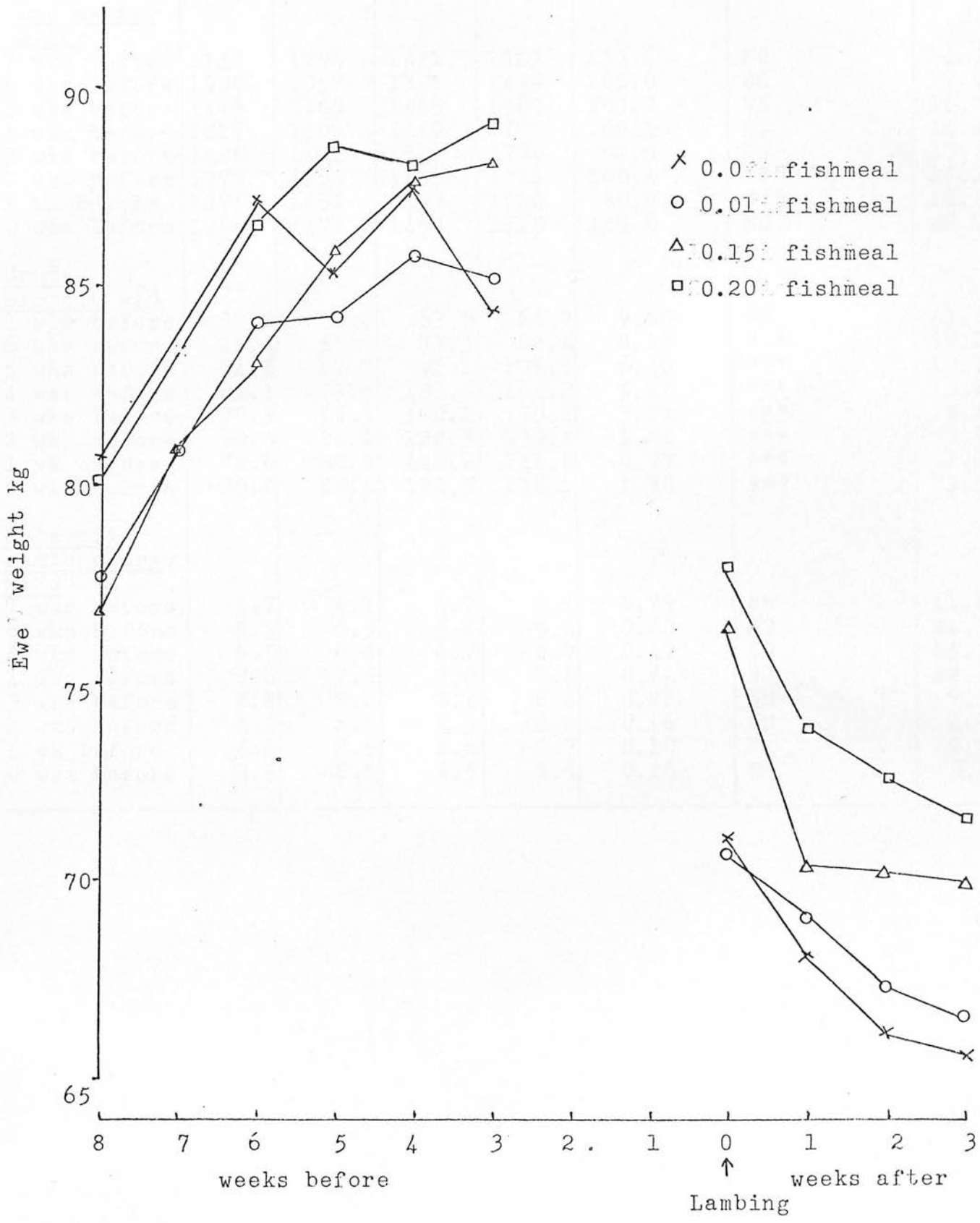


Table 9.3a Nutrient intakes before lambing

Treatments	1	2	3	4	SE of the difference	Level of significance	CV %
Time Dry matter g/day							
7 wks before	1148	1298	1321	1223	137.6	NS	24.7
6 wks before	1390	1357	1346	1433	105.0	NS	17.0
5 wks before	1415	1409	1485	1589	103.7	NS	15.7
4 wks before	1527	1506	1499	1707	100.2	NS	14.4
3 wks before	1488	1472	1541	1700	92.6	NS	13.4
2 wks before	1370	1354	1453	1716	100.4	**	15.2
1 wk before	1375	1431	1497	1720	80.2	***	11.9
0 wks before	1396	1471	1458	1519	148.0	NS	22.7
Crude protein g/d							
7 wks before	32.8	40.6	63.9	64.7	9.60	**	42.5
6 wks before	45.4	55.7	73.3	82.4	8.28	***	28.8
5 wks before	54.5	67.7	92.1	105.6	6.46	***	18.1
4 wks before	64.1	79.5	108.3	124.2	5.82	***	13.8
3 wks before	70.3	85.5	120.1	135.2	3.71	***	8.1
2 wks before	70.5	86.2	122.3	139.1	1.84	***	3.9
1 wk before	70.6	87.2	122.8	141.0	0.97	***	2.1
0 wks before	70.8	87.6	122.3	138.6	1.70	***	3.8
Metabolisable energy MJ/d							
7 wks before	3.7	4.1	4.7	4.4	0.79	NS	41.1
6 wks before	5.3	5.5	5.4	5.4	0.60	NS	24.3
5 wks before	6.5	6.6	6.7	6.7	0.47	NS	15.4
4 wks before	7.6	7.8	7.8	7.8	0.44	NS	12.4
3 wks before	8.4	8.4	8.4	8.4	0.28	NS	7.3
2 wks before	8.4	8.4	8.5	8.6	0.16	NS	4.1
1 wk before	8.4	8.5	8.6	8.7	0.10	*	2.7
0 wks before	8.5	8.6	8.5	8.5	0.20	NS	5.1

The nutrient intakes in lactation are given in Table 9.3b. The protein intakes are significantly different reflecting the protein concentration of the concentrate. Again dry matter and to a lesser extent metabolisable energy show a trend towards increasing intake as protein concentration increases. Only in week 3 does the difference in dry matter intake reach significance. The physical handling of swedes led to an unintentional restriction in intake. As time progressed the restriction was alleviated but not completely removed. Intakes of hay and swedes were highly variable as indicated by the high coefficients of variation.

9.3iii Milk yield Ewes on treatments 3 and 4 yielded more milk than the ewes on treatments 1 and 2. (Table 9.4). The difference was not significant in the early stages, up to the first week's recording, but it was highly significant in the third week when the yield of ewes on treatment 1 dropped. Overall yields were significantly different ($p < 0.01$). Figure 9.2 shows the cumulative milk yield and illustrates the greater differences between the lower levels of fishmeal and the 0.15 and 0.20 levels.

9.3iv Milk composition Table 9.5 shows the concentration of constituents in milk at the time of yield measurement each week. The only significant difference was the increasing concentration of protein as protein concentration of the diet increased. This may have occurred at an earlier stage, but protein concentration was not measured for the first, second and third week.

The yield of milk constituents is given in Table 9.6. From the second week onwards yield of fat and dry matter

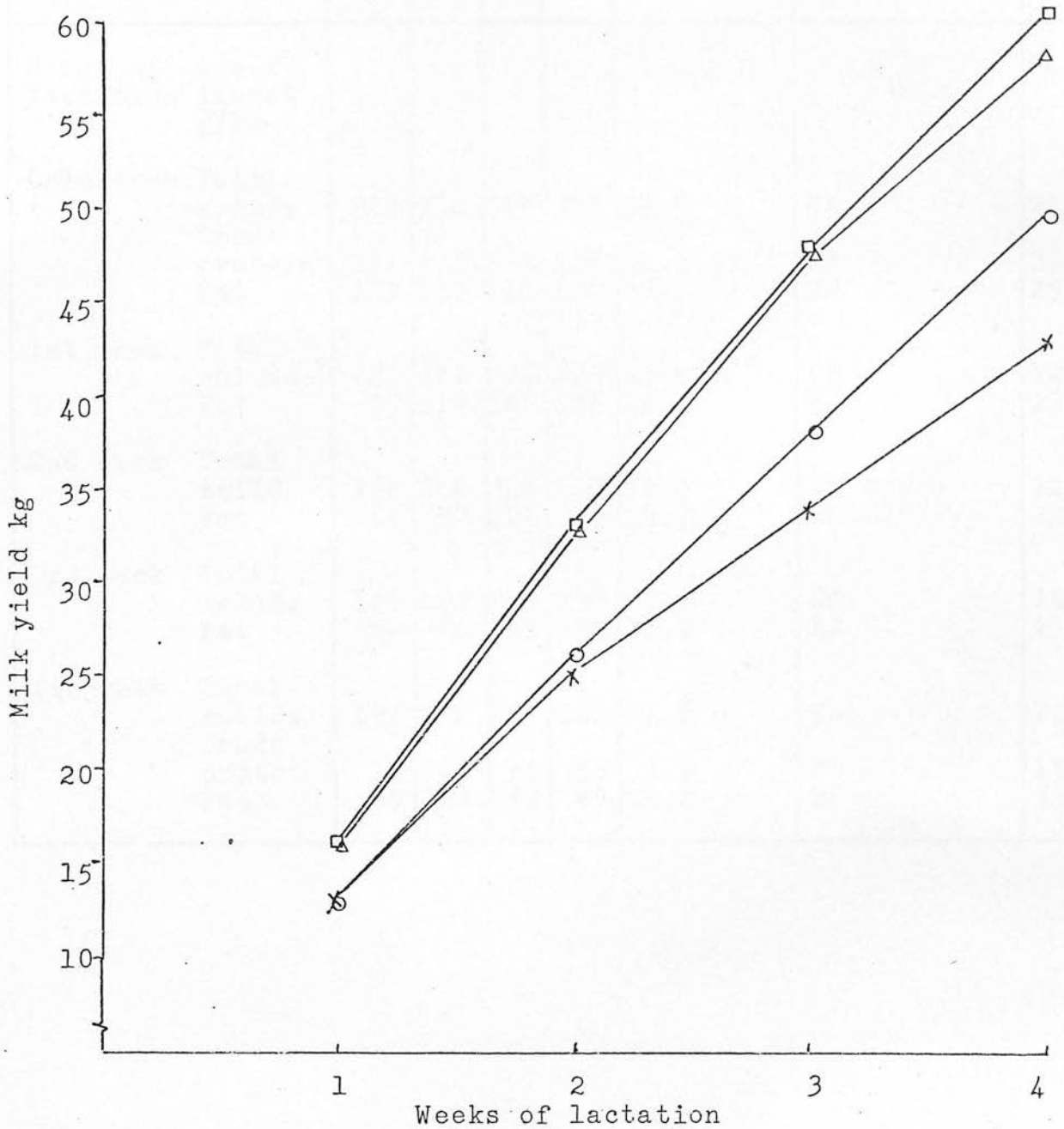
Table 9.3b Total nutrient intake in lactation

Treatments	1	2	3	4	SE of the difference	Level of significance	CV %
Dry matter intake g/d							
Lactation							
week 1	1198	1261	1329	1242	83.3	NS	14.8
week 2	1442	1521	1624	1559	132.6	NS	19.3
week 3	1480	1670	1904	1855	153.4	*	19.9
week 4	1486	1736	1947	1815	173.0	NS	22.2
Crude protein intake g/d							
Lactation							
week 1	92.8	109.4	145.0	159.5	0.87	***	1.5
week 2	95.4	112.1	148.0	162.8	1.38	***	2.4
week 3	95.8	113.7	151.0	165.9	1.60	***	2.7
week 4	95.8	114.3	151.4	165.5	1.80	***	3.1
Metabolisable energy MJ/d							
Lactation							
week 1	11.4	11.6	11.8	11.5	0.24	NS	4.7
week 2	11.4	11.6	11.8	11.5	0.24	NS	4.7
week 3	11.5	11.9	12.3	12.1	0.28	NS	5.3
week 4	11.5	12.0	12.4	12.0	0.32	NS	5.9

Table 9.4 Daily milk yield corrected for sex

Treatment	1	2	3	4	SE of the difference	Level of significance	CV %
Weight g							
Colostrum	1669	1682	2000	2118	203.5	NS	23.9
1st week	1914	1893	2470	2305	229.6	*	23.5
2nd week	1806	1814	2371	2339	239.7	*	25.3
3rd week	1283	1688	2253	2090	207.9	***	25.0
4th week	1315	1562	1635	1837	168.6	*	23.3
Total kg	42.9	49.7	58.6	61.0	5.04	**	21.2

Figure 9.2 Cumulative milk yield



(Symbols represent same treatments as Figure 9.1)

Table 9.5 Concentration of constituents in milk during first 4 weeks of lactation corrected for lamb sex

Treatment		1	2	3	4	SE of the difference	Level of significance	CV %
Stage of lactation	Const-ituent g/kg							
Colostrum	Total solids	322	316	318	323	32.9	NS	22.3
	Crude protein	151	159	153	160	22.4	NS	31.1
	Fat	123	145	146	136	16.1	NS	25.3
1st week	Total solids	221	221	220	205	13.0	NS	12.1
	Fat	99	112	107	98	12.1	NS	23.7
2nd week	Total solids	198	206	218	207	11.5	NS	12.0
	Fat	91	97	109	97	9.7	NS	21.4
3rd week	Total solids	189	190	201	190	9.2	NS	10.5
	Fat	90	86	95	79	11.0	NS	27.5
4th week	Total solids	194	202	207	201	11.6	NS	12.7
	Crude protein	46	48	55	55	3.7	*	15.9
	Fat	90	87	93	87	9.4	NS	23.1

Table 9.6 Yield of milk constituents during first 4 weeks of lactation corrected for lamb sex

Treatment		1	2	3	4	SE of the difference	Level of significance	CV %
Stage of lactation	Constituent g							
Colostrum	Total solids	528	523	634	683	76.1	NS	27.9
	Crude protein	244	265	297	332	41.2	NS	31.4
	Fat	209	246	288	292	41.7	NS	35.0
1st week	Total solids	402	419	523	491	58.9	NS	26.1
	Fat	173	212	255	234	34.3	NS	32.0
2nd week	Total solids	331	374	495	490	52.3	**	26.7
	Fat	149	178	246	232	32.9	*	35.3
3rd week	Total solids	240	325	445	420	42.4	***	26.0
	Fat	110	148	210	177	24.9	**	33.8
4th week	Total solids	253	316	329	363	31.4	*	21.9
	Crude protein	61	74	86	99	6.8	***	18.7
	Fat	115	137	146	156	16.8	NS	26.6

increased as protein concentration of the diet increased and yield of crude protein increased by over ·50 from treatments 1 to 4.

9.3v Lamb weights Lamb birth weights were not significantly different (Table 9.7) although the trend followed expectations, that ewes fed more fishmeal produced heavier lambs, albeit insignificant. By four weeks, lamb weights had diverged and lambs on treatments 3 and 4 were about 2 kg heavier than lambs from ewes on treatment 1.

By weaning, there were no differences in lamb weights. The growth rates in Table 9.8 show that, while growth rate of lambs from ewes on treatment 1 was depressed during the treatment period, the overall growth rate from birth to weaning was similar to lambs from ewes on other treatments.

9.3vi Lamb mortality One lamb was lost from treatment 3 as it was born with membranes over its nose. This loss was not considered to be as a result of treatment. Two lambs from separate pairs were lost later from ewes on treatment 1. One developed an abscess under its chin and had difficulty sucking. In the other case, the ewe had developed mastitis and the lamb died from starvation. A third lamb from another pair on treatment 1 was removed and artificially reared because it was receiving very little milk from the ewe.

9.4 Discussion

The pattern of liveweight and condition score change in relation to treatment were, to some extent, unexpected. Cowan, Robinson, McHattie and Pennie's (1981) work would

Table 9.7 Mean lambs weights from birth to four weeks and at weaning (28.7.81)

Treatment	1	2	3	4	SE of the difference	Level of significance	CV %
Weight kg							
Birth	4.47	4.77	5.09	4.89	0.246	NS	11.4
1 week	5.95	6.02	6.65	6.57	0.371	NS	13.2
2 weeks	6.89	7.23	8.15	8.07	0.435	*	12.8
3 weeks	7.64	8.17	9.40	9.57	0.514	***	13.2
4 weeks	8.56	9.14	10.44	10.75	0.564	***	13.0
Weaning	35.5	34.5	36.3	36.4	1.75	NS	11.9

Table 9.8 Average age of lambs at weaning and growth rates over different periods

Treatment	1	2	3	4	SE of the difference	Level of significance	CV %
Age at weaning days	120.3	119.4	119.7	119.4	2.68	NS	5.0
Growth rates g/day							
Birth to 4 weeks	145	156	206	209	15.4	***	19.1
4 weeks to weaning	288	278	276	278	15.5	NS	12.4
Birth to weaning	259	250	260	263	13.2	NS	11.4

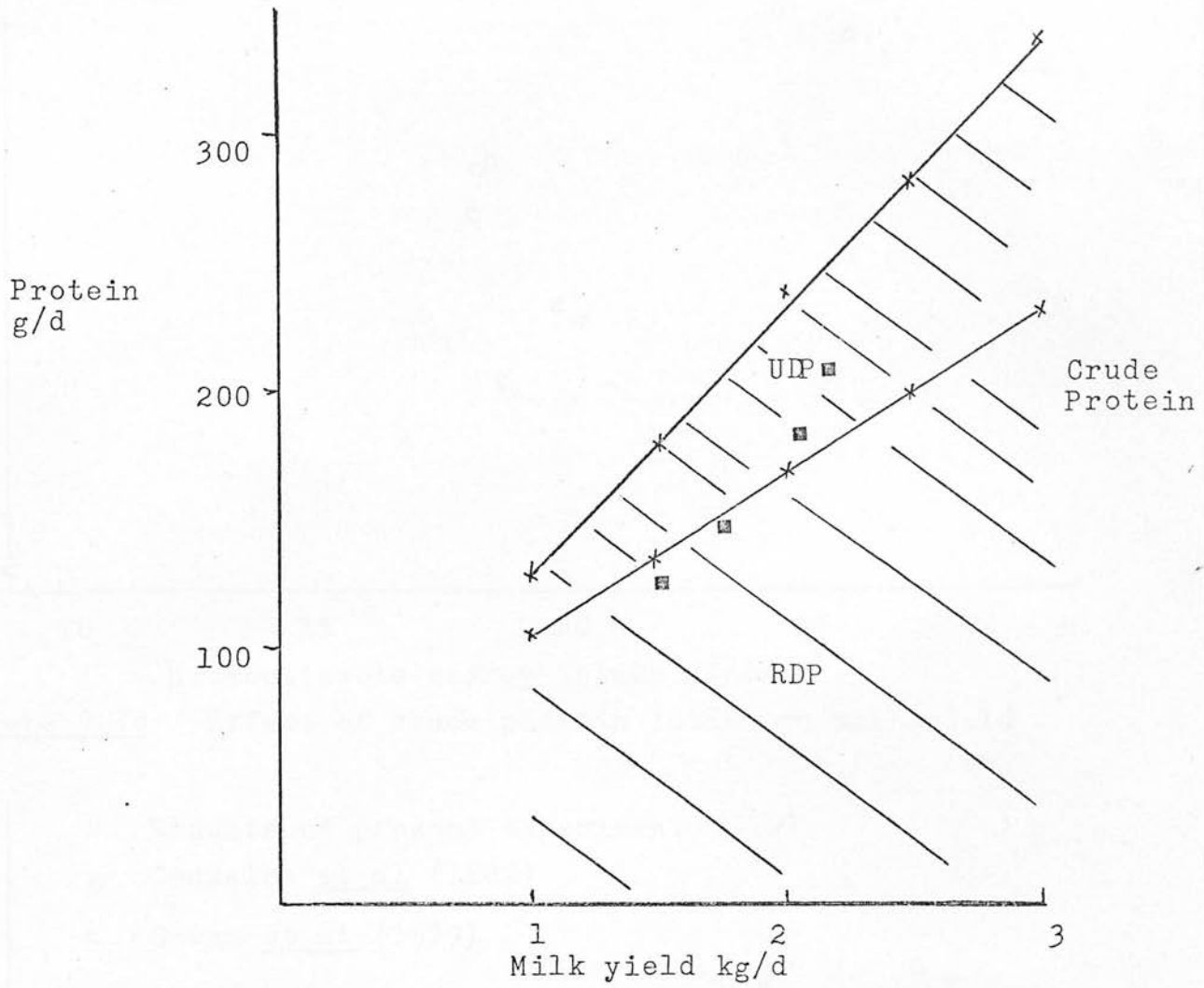
suggest that at higher levels of protein, in particular, undegradable protein, the mobilisation of body reserves is facilitated thus leading to a greater weight loss in animals on higher protein levels. Variability in hydration of body tissue in early lactation makes liveweight a poor indicator of body energy changes, but trends in empty body weight would be expected to reflect liveweight changes. This has been illustrated in the dairy cow at low metabolisable energy intakes (Ørskov, Reid and McDonald, 1981). In the present experiment, the roughage was offered ad libitum and intakes increased with increasing fishmeal inclusion, therefore it would seem that the protein-energy balance was achieved by an increased intake of roughage, rather than from mobilisation of body reserves.

Intakes of swedes were severely restricted. A two to four fold increase would have been a more realistic amount to meet requirements. Figure 9.3a and b show requirements predicted in ARC (1980) in relation to the allowance fed. Nevertheless, the relationship between voluntary intake and fishmeal inclusion still persisted and it is possible that a larger effect would have been observed if swedes had not been restricted.

As a result of nutrient intake limitations, milk yield was proportionately lower than might have been expected. Aligning the data with figures given by Gonzalez et al (1982) and Cowan et al (1980) (Figures 9.4a and b) it is evident that milk yield obtained corresponded to the nutrients consumed at the lower part of the curve.

The concentration and yield of constituents was also

Figure 9.3a Rumen-degradable (RDP) and undegraded (UDP) protein requirements (g/day) of lactating ewes kept out of doors predicted by ARC (1980) (75 kg ewe losing 100 g/d q = 0.5)



b. Metabolisable energy requirements of ewes (75 kg ewe losing 100 g/d q = 0.5)

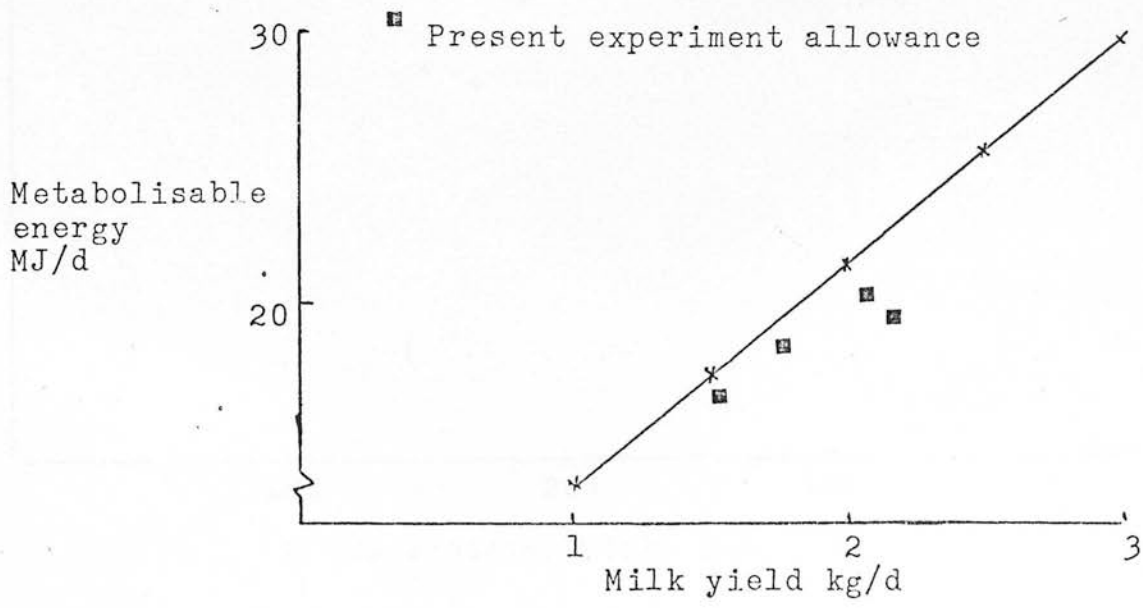


Figure 9.4a Effect of metabolisable energy intake on milk yield

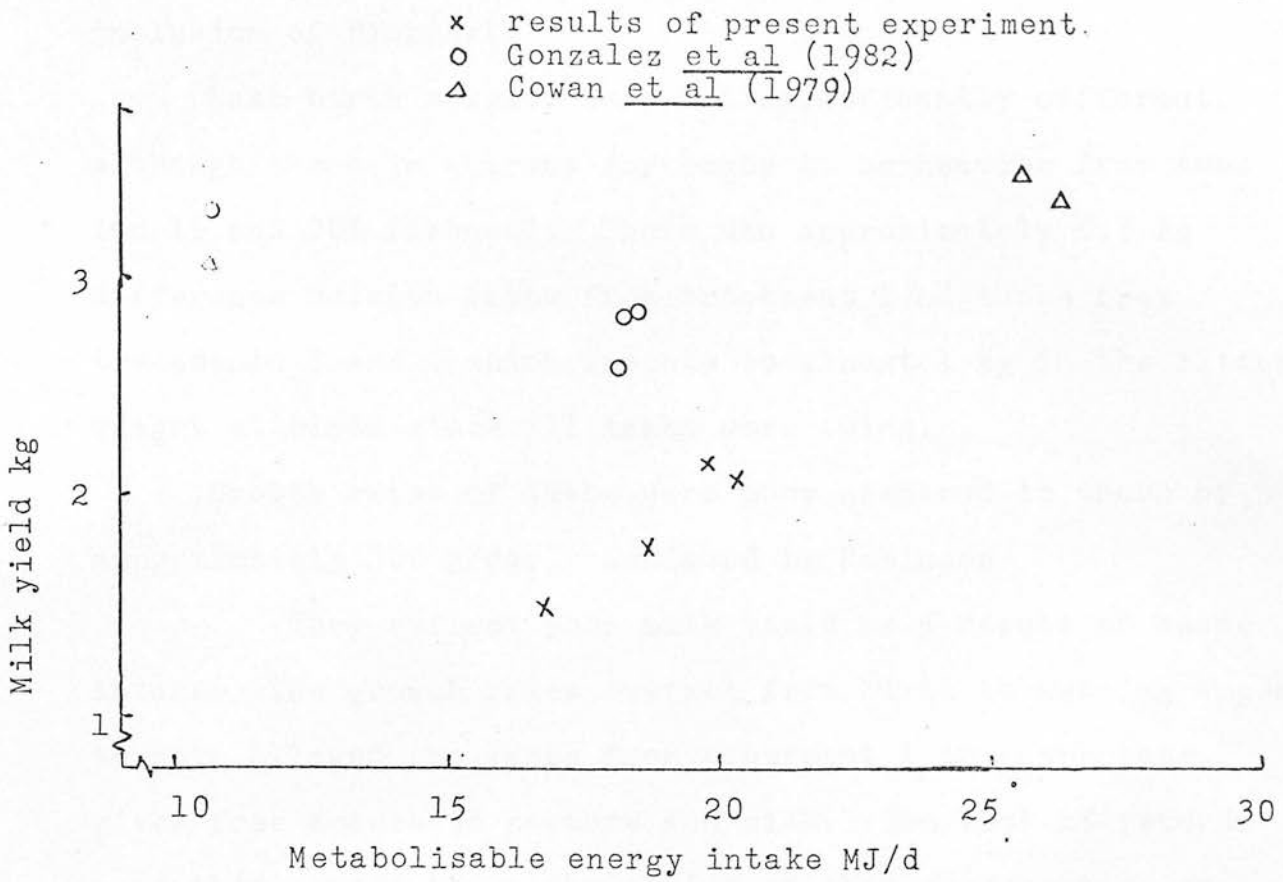
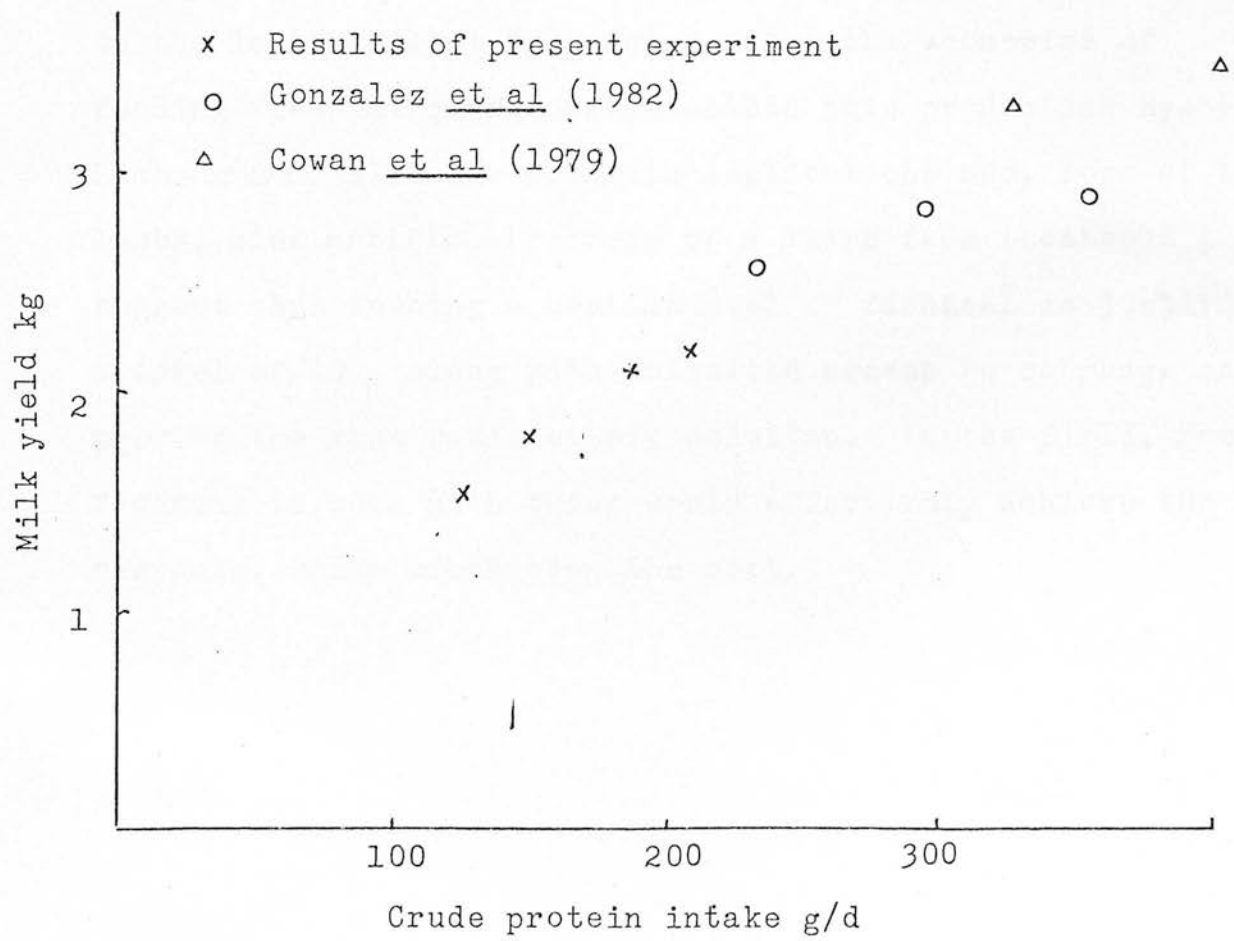


Figure 9.4b Effect of crude protein intake on milk yield



affected by treatment in that they increased with increasing inclusion of fishmeal.

Lamb birth weights were not significantly different, although there is a trend for lambs to be heavier from ewes fed 15 and 20% fishmeal. There was approximately 0.5 kg difference between lambs from treatment 1 and those from treatments 3 and 4 which amounts to almost 1 kg in the litter weight at birth since all lambs were twins.

Growth rates of lambs were poor compared to those of approximately 300 g/day achieved by Robinson

They reflect poor milk yield as a result of swede intake. The growth rates overall from birth to weaning appear to have allowed the lambs from treatment 1 to compensate, given free access to pasture and milk. The lack of records over this period leave the timing of this compensation to speculation. The fact that the advantage in weight gain to the lambs is lost by weaning makes the economics of feeding fishmeal questionable within this production system. Lamb survival also has economic implications and, loss of two lambs, plus artificial rearing of a third from treatment 1 would suggest that feeding a certain level of fishmeal is justifiable. A level of 10 , along with unlimited access to roughage may provide the most satisfactory solution. In the field, feeding fishmeal to ewes with twins would effectively achieve the response, while minimising the cost.

CHAPTER 10

GENERAL DISCUSSION AND CONCLUSIONS

The aim of ewe nutrition in commercial practice is to produce a viable lamb of optimum birthweight, while utilising ewe body reserves without long term detrimental effects.

The objectives of the study were firstly to examine the effect of pre-mating and early pregnancy nutrition on the growth and development of the foetus and on maternal body composition. Secondly, the effects of late pregnancy and lactation protein and energy nutrition were investigated in relation to foetal growth, milk yield and lamb growth.

10.1 Ewe weight and body composition

Experiments 1 and 2 showed clearly that nutritional restriction before mating or in early pregnancy resulted in a decrease in body energy reserves which was only partly reflected in liveweight loss. While there was only a 0.31 difference in liveweight, energy contents differed by 0.52 and body fat contents by 0.56 in experiment 1.

In late pregnancy (experiment 2) weight gains were observed on all treatments, but losses in fat, energy and even protein were observed. Rates of change of these constituents are given in Table 10.1. The positive direction of weight change may be attributed to the growth of the conceptus and to the increase in water concentration in the maternal body. This is in agreement with the work of Robinson, Smart and Pennie (1978) at the Rowett Institute.

Protein catabolism indicates that there is a high demand for this nutrient which has not been fully appreciated in

Table 10.1 Rates of liveweight, fat protein and energy change calculated from 90 to 142 days of gestation (experiment 2)

Treatment Premating	High			Low		
Late pregnancy	HEHP	LEHP	LELP	HEHP	LEHP	LELP
Liveweight gain g/d	178	115	73	216	124	64
Fat loss g/d	77	104	88	40	50	55
Protein loss g/d	4	9	18	4	5	19
Energy loss MJ/d	2.9	4.2	3.9	1.8	2.1	2.6

Table 10.2 Loss of fat, protein and energy from 90 to 142 days of gestation as a proportion of the whole at 90 days (experiment 2)

Treatment Premating	High			Low		
Late pregnancy	HEHP	LEHP	LELP	HEHP	LEHP	LELP
Fat	0.27	0.36	0.34	0.22	0.29	0.31
Protein	0.04	0.08	0.16	0.04	0.05	0.19
Energy	0.21	0.31	0.31	0.19	0.23	0.28

the past. It has been suggested that the use of maternal protein would be resisted according to the theory of the priority of nutrients in relation to functional necessity (Hammond, 1952).

From Table 10.1 it can be seen that the leaner ewes (low pre-mating treatment) tended to have a slower rate of loss of fat and energy. This applied to the proportion of loss (Table 10.2) as well as absolute loss. It may be that as the total body reserves decrease, the ewe decreases the ability to mobilise these reserves.

10.2 Implications of foetal and cotyledon weight

Normally the weight gain of the placenta and cotyledons is complete in sheep by ninety days of gestation. This is thought to provide the structure for nutrient supply to the foetus when growth is rapid in the last trimester.

From experiment 1 it might be suggested that the differences in placental and cotyledon weight resulting from premating and early pregnancy treatment might influence the later nutrient supply and hence the subsequent growth and development of the foetus (Everitt, 1964).

Experiment 2 did not confirm the differences in placental growth due to premating treatment, but in that experiment the ewes were fed a maintenance level through early pregnancy. Effects on placental growth may depend on both pre- and post-mating nutrition. The placenta and cotyledons gained about 100 g or 0.2 of their weight between ninety days and term. The exact stage at which this occurred is not known, but it suggests that placental compensation may occur. There were no significant differences in placental and cotyledon weight due to treatment.

This may be explained by the fact that nutritional restriction was not sufficiently severe to differentially limit the development of these tissues in the pre-mating to early pregnancy period and late pregnancy nutrition allowed growth.

Foetal weight was not significantly affected at ninety days of gestation in the first or second experiment, but this was expected, as the weight of the foetus was only 0.15 of its final birth weight at this point.

In experiment 2 the lambs at term were significantly affected by protein treatment in late pregnancy. The lambs from ewes on high protein weighed approximately 1 kg more than those on low protein. Clearly protein nutrition in late pregnancy has had an important effect on lamb birth weight. Alexander (1974) has discussed the implications of low birth weight and shows that the small lamb has not only low weight, but lower energy reserves per unit weight, which may mean that it is less viable at birth.

In the last experiment little effect was observed in birth weight as the range of protein was less extreme even between treatments 1 and 4. The effect of protein on milk yield was reflected in increasing growth rate of the lambs with increasing protein intake, resulting in 2 kg difference after four weeks of lactation. In looking at the lack of difference in weaning weights it might be concluded that there is no economic justification for feeding high levels of fishmeal to ewes around lambing time. It is most important to remember the effect of treatments on lamb loss and viability. Three lambs were lost from treatment 1 as a result of treatment. While it is dangerous to extrapolate this as a proportion to

a large flock, the loss of 0.15 of lambs would seriously affect the profitability of an enterprise.

10.3 Energy and protein balance

The energy balances from Sykes and Field (1972) and Experiment 2 are given in Tables 10.3a and 10.3b respectively. There are limitations in the calculation from the present study as pelt, head, feet and blood were not analysed and therefore any changes were excluded. Also the energy gain of the conceptus does not include the fluids, although these contain very little energy. Providing these limitations are accepted the results may be discussed. Sykes and Field's (1972) results refer to the final 112 days compared with the final 52 days of the present study, but each is expressed on a daily basis. The two experiments were carried out at different feeding levels. Sykes and Field's (1972) intakes were much lower than those in the present experiment and energy lossess were less, but this may be attributed to the smaller ewe and the longer duration of the experiment. The protein concentrations were lower at 0.118 g/kg DM and 0.060 g/kg DM for high and low protein treatments respectively. Nevertheless efficiencies of utilisation of energy were of a similar order and were in agreement with those of Robinson, McDonald, Fraser and Gordon (1980). At the higher protein level the efficiency of utilisation was greater. The present results suggest that when energy reserves are lower, in this case as a result of pre-mating treatment, efficiency of utilisation is greater. Robinson et al (1980) (Table 10.4) show that efficiency of energy utilisation is also greater at a low compared with a

Table 10.3a Mean daily energy utilisation (MJ) during the final 112 days of pregnancy

	High protein	Low protein
EWE		
ME intake	5.6	5.2
Energy intake of body fat	1.2	1.2
Energy intake of body protein	0.2	0.3
Total ME used for maintenance and foetal development	7.0	6.7
ME requirement for maintenance	5.7	5.5
ME available for foetal development	1.3	1.2
LAMB		
Energy content of body fat	0.03	0.02
Energy content of fat-free soft tissues	0.13	0.09
Energy content of uterine membranes	0.02	0.02
Energy losses in 6 hours between birth and slaughter	0.02	0.01
Total energy content of conceptus	0.19	0.15
Gross efficiency of utilisation of energy for foetal development*	0.142	0.124

Source: Sykes and Field (1972)

* The figures have been converted from the original calories leading to some discrepancies, but the original gross efficiencies have been quoted.

Table 10.3b Mean daily energy utilisation (MJ) during the final 52 days of pregnancy

Premating treatment	High			Low		
Late pregnancy treatment	HEHP	LEHP	LELP	HEHP	LEHP	LELP
Metabolisable energy intake	12.6	11.1	10.0	12.8	11.0	10.0
Loss of energy from body	2.9	4.3	4.0	1.8	2.3	2.6
Total ME used for maintenance and foetal development	15.5	15.4	14.0	14.6	13.3	12.6
ME requirement for maintenance*	8.9	8.9	8.7	8.0	8.0	7.9
ME available for foetal development	6.6	6.5	5.3	6.6	5.3	4.7
Estimated energy gain of lamb 90 - 142 days+	0.72	0.74	0.56	0.70	0.70	0.59
Energy gain of uterine membranes 90 - 142 days	0.05	0.04	0.01	0.06	0.05	0.03
Total energy gain of conceptus	0.77	0.78	0.57	0.76	0.75	0.62
Gross efficiency of utilisation of energy for foetal development	0.117	0.120	0.108	0.143	0.142	0.132

* Calculated from ARC (1980)

\+ Energy concentration used from Robinson, McDonald, Fraser and Gordon (1980)

Table 10.4 Gross efficiency of utilisation for foetal growth over the last 8 weeks of pregnancy for twin lambs

Level of feeding	Total energy for pregnancy (MJ/d)	Foetal energy gain (MJ/d)	Gross efficiency of utilisation
L	4.01	0.65	0.163
H	5.51	0.65	0.118

Source: Robinson, McDonald, Fraser and Gordon (1980)

high feeding level. The ewe would appear to compensate when resources, dietary or body reserves, are in short supply by improving efficiency of utilisation. The ability to utilise energy is improved when the diet quality, that is protein concentration is higher.

The protein intake was much higher in the present studies compared with Sykes and Field (1972) and body protein losses were much lower (Tables 105a and 105b). The efficiencies of utilisation were of a similar order for the ewes fed high protein in the present work, but were about 0.1 higher for the ewes fed on the low level of protein. Like energy utilisation, protein utilisation appears to improve when the resource is in short supply. As no HELP treatment was imposed in the present studies it is not possible to determine the effect of energy availability.

Sykes and Field (1972) associate the improved efficiency with a reduced amino acid supply which would have reduced growth. In the high protein group, protein in excess of requirements would have been de-aminated. Although energy intake was higher in the present experiment, growth was probably limited.

10.4 Milk yield response

The response to increasing protein level in milk yield, was limited by the unintentional restriction in swede intake. When plotted with other data on response in milk yield to protein intake (Figure 10.1) it can be seen that it falls at the lower end of the curve. Had this restriction in intake been lifted larger differences in milk yield and hence lamb growth rate might have been expected. The response

Table 10.5a Mean protein balance (g) during pregnancy

	High protein	Low protein
Total DCP intake	3427	1343
Loss of body protein	1631	1995
Total	5058	3338
Ewe maintenance requirement	1736	1664
Remaining for foetal development	3322	1674
Protein content of lamb	623	424
Estimated protein content of uterine membranes	61	61
Loss of protein at lambing	684	485
Gross efficiency of utilisation for foetal development	0.21	0.29

Source: Sykes and Field (1972)

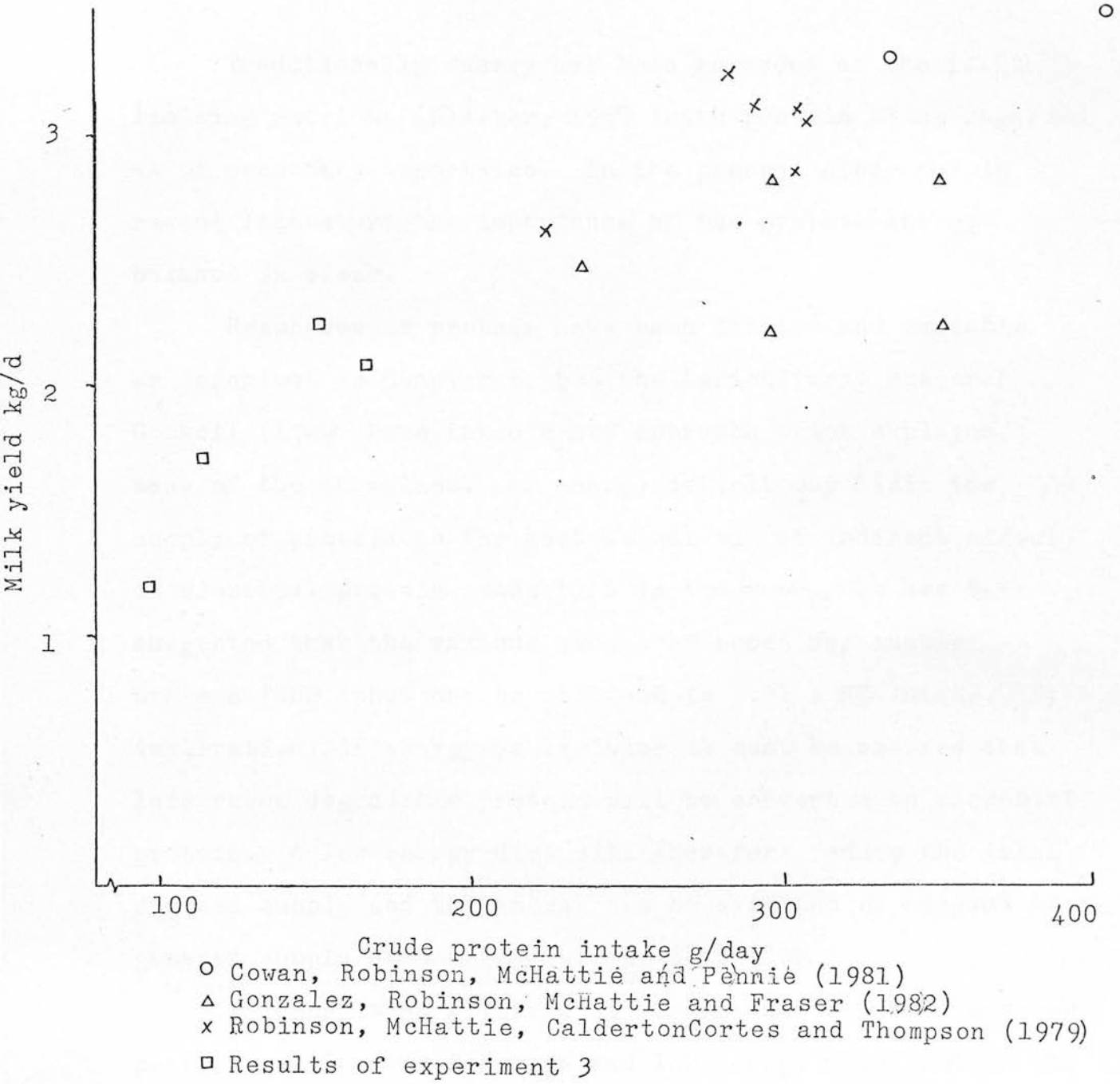
Table 10.5b Mean protein balance (g) between 90 and 142 days of gestation (Experiment 2)

Premating treatment	High			Low		
Late pregnancy treatment	HEHP	LEHP	LELP	HEHP	LEHP	LELP
Total DCP intake	6042	5989	2544	6095	5936	2544
Loss of body protein	220	480	995	186	226	983
Total	6262	6469	3539	6281	6162	3527
Ewe maintenance requirement*	942	942	919	864	864	857
Remaining for foetal development	5320	5527	2620	5417	5298	2670
Estimated protein gain of lamb +	1209	1240	939	1162	1158	979
Protein gain of uterine membranes	142	131	71	140	139	79
Loss of protein at lambing	1351	1371	1010	1302	1297	1048
Gross efficiency of utilisation for foetal development	0.254	0.248	0.385	0.240	0.245	0.393

* Calculated from ARC (1980)

\+ Protein concentration used from McDonald, Robinson, Fraser and Smart (1979)

Figure 10.1 Effect of crude protein intake on milk yield



measured was at the lower end of the curve, where large increases in yield were observed in response to relatively small increases in protein intake. Further up, the response tends to plateau and yields at a constant protein intake may depend on energy.

10.5 Responses to nutrition

Traditionally energy has been regarded as the first limiting nutrient (Blaxter, 1957) with protein being regarded as of secondary importance. In the present study and in recent literature the importance of the protein-energy balance is clear.

Responses to protein have been limited and variable as described in Chapter 5, but the Agricultural Research Council (1980) have taken a new approach which explains many of the anomalies. An energy deficit may limit the supply of protein to the host animal via an indirect effect on microbial protein production in the rumen. It has been suggested that the maximum amount of rumen degradable protein (RDP) that can be utilised is 7.81 x ME intake. By implication, if energy is limiting it must be assumed that less rumen degradable protein will be converted to microbial protein. A low energy diet will therefore reduce the total protein supply and the animal can be expected to respond to a greater supply of undegradable protein (UDP).

In experiment 2 little difference was observed between performance in ewes fed high and low energy when protein was high, but a marked decrease in lamb birth weight was observed

when low protein was offered. The high protein may have enabled energy to be used more efficiently, and the undegradable protein component may have allowed the use of body reserves.

The response in milk yield in experiment 3 was a result of increasing protein level. Part of the response was indirect through increasing intake of the basal diet which was offered ad libitum and hence increasing energy supply. The other part was due to increasing the supply of UDP in the form of fishmeal.

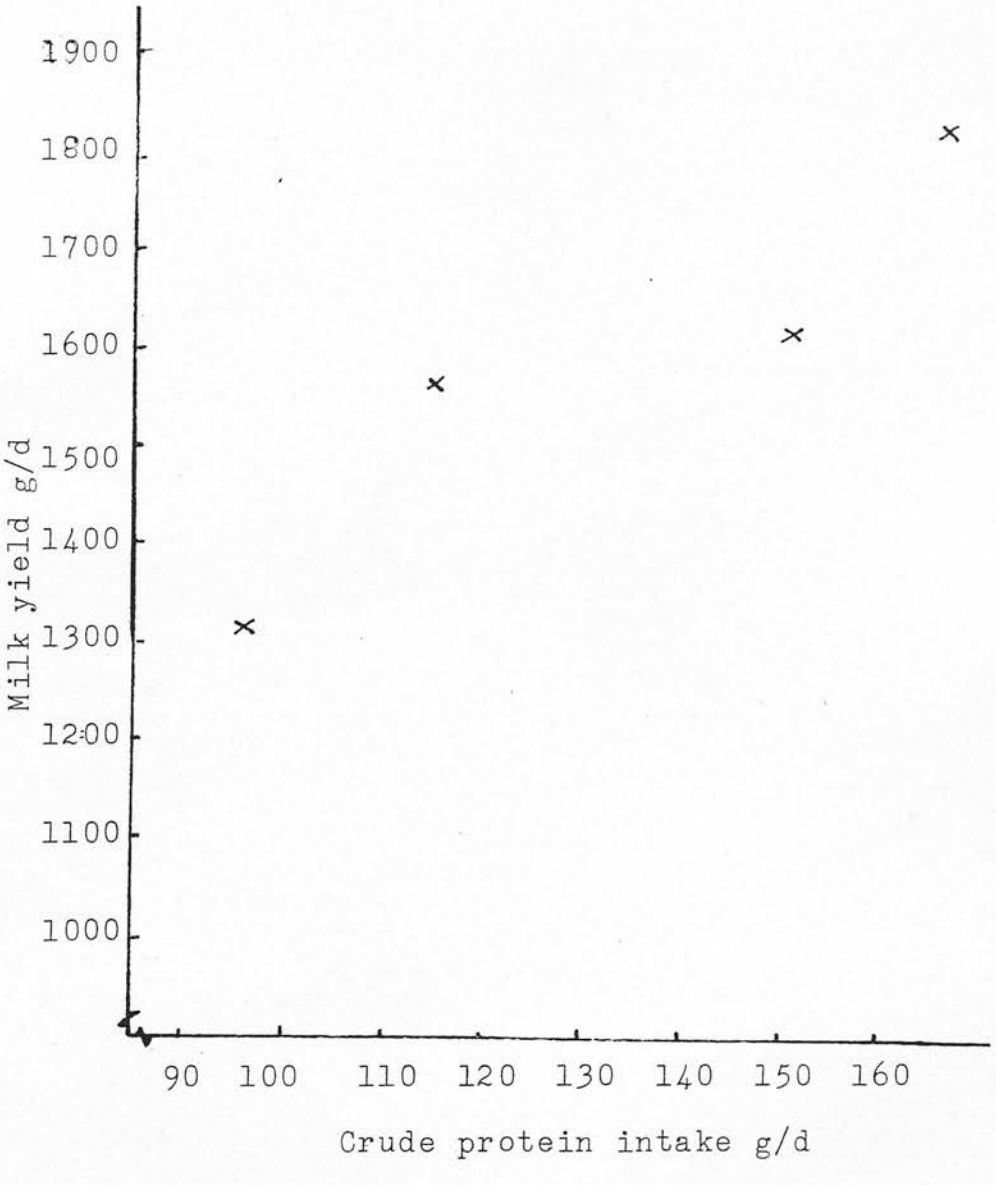
10.6 Practical observations

In managing the commercial flock it is important to have ewes in good condition and a rising plane of nutrition to achieve satisfactory ovulation and conception rates. This is important also for satisfactory placental and cotyledon growth and development during early pregnancy, particularly when nutritional conditions might be poor in the period following mating. When ewes are mated in October to November, poor subsequent nutrition is a common occurrence.

In late pregnancy ewes and lambs benefit from a certain level of protein in the diet, but it is essential to supply adequate quantities of the basal diet on an ad libitum basis. In this way, lamb viability, survival and early growth rate will benefit. If grassland management is good, or in the indoor feeding conditions of an early lambing flock, it may be possible to maintain the advantage of weight gain and to finish lambs earlier.

Present commercial practice for feeding ewes is likely

Figure 10.2 Relationship between crude protein intake and milk yield in the fourth week of lactation



to result in ewes being in energy deficit and levels of protein in the ration may be around 140 - 150 g/kg DM. It may not be possible to meet a ewe's energy requirements economically, but the importance is in the protein-energy balance. Small quantities of good quality protein may be included in the ration to improve efficiency of energy utilisation.

10.7 Conclusions

i Pre-mating nutrition can affect placental development, but if adequate nutrition is provided in early and late pregnancy, compensation may occur.

ii Under the circumstance of experiment 2, a high protein level enabled dietary energy and maternal energy reserves to be used more efficiently for foetal growth.

iii An increased protein concentration in the ration in the form of fishmeal, results in increased intake of a basal diet, increased milk yield and lamb growth rate.

REFERENCES

AGRICULTURAL RESEARCH COUNCIL (1965) Nutrient requirements of farm livestock No 2 Ruminants. London HMSO.

AGRICULTURAL RESEARCH COUNCIL (1980) The Nutrient Requirements of Ruminant Livestock. Technical review by an Agricultural Research Council Working Party. Commonwealth Agricultural Bureaux.

ALEXANDER, G. (1964a) Studies on the placenta of the sheep. (Ovis aries L.) J. Reprod. Fert. 7, 289-305.

ALEXANDER, G. (1964b) Studies on the placenta of the sheep. (Ovis aries L.) Effect of surgical reduction in the number of caruncles. J. Reprod. Fert. 7, 307-322.

ALEXANDER, G. (1974) Birth weight of lambs: influences and consequences. In Size at Birth eds. K. Elliot and J. Knight pp 215-245. Associated Scientific Publishers, Amsterdam.

ALEXANDER, G. and WILLIAMS, D. (1971) Heat stress and development of the conceptus in domestic sheep. J. agric. Sci. 76, 53-72.

ALLEN, D.M. and LAMMING, G.E. (1961) Nutrition and reproduction in the ewe. J. agric. Sci. Camb. 56, 69-79.

AMOROSO, E.C. (1952) Placentation. In Marshall's Physiology of Reproduction ed. A.S. Parkes Vol 2, pp 127-311. Longmans Green and Co, London.

ANNISON, E.F. (1960) Plasma non-esterified fatty acids in sheep. Aust. J. Agric. Res. 11, 58-64.

AUSTIN, A.R. and YOUNG, N.E. (1977) The effect of shearing pregnant ewes on lamb birth weight. Vet. Rec. 100, 527-529.

BARNICOAT, C.R., LOGAN, A.G. and GRANT, A.L. (1949) Milk secretion studies with New Zealand Romney ewes. Parts I and II. J. agric. Sci., Camb. 39, 44-55.

BARNICOAT, C.R., MURRAY, P.F., ROBERTS, E.M. and WILSON, G.S. (1957) Milk secretion studies with New Zealand Romney ewes. J. agric. Sci., Camb. 48, 9-35.

BASSETT, J.M. (1968) The relation of fat and protein catabolic actions of coritsol to glucose homesostasis in fasting sheep. Metabolism, 17, 644-652.

BATTAGLIA, F.C. and MESCHIA, G. (1981) Foetal and placental metabolisms: their interrelationships and impact upon maternal metabolism. Proc. Nutr. Soc. 40, 99-113.

BEATTY, R.A. (1956) Relation between genetic constitution of an offspring and weight of its litter mates. Nature (Lond.) 178, 48-49.

BEATTY, R.A. (1957) A pilot experiment with heterospermic insemination in the rabbit. J. Genetics 55, 325.

BEATTY, R.A. (1960) The birth weight of rabbits born after heterospermic insemination. Genet. Res. (Camb.) 1 39

BENNETT, D., AXELSEN, A. and CHAPMAN, H.W. (1964) The effect of nutritional restriction during early pregnancy. Proc. Aust. Soc. Anim. Prod. 5, 70-81.

BENNETT, D., NADIN, J.B. and AXELSEN, A. (1970) The effect of undernutrition during early pregnancy in Merino ewes. Proc. Aust. Soc. Anim. Prod. 8, 362-365.

BINES, J.A., SUZUKI, S. and BALCH, C.C. (1969) The quantitative significance of long term regulation of food intake in the cow. Br. J. Nutr. 23, 695-704.

BISHOP, M.W.H. (1964) Paternal contribution to embryonic death. J. Reprod. Fert. 7, 383-396.

BLAXTER, K.L. (1957) The effects of defective nutriton during pregnancy in farm livestock. Proc. Nutr. Soc. 16, 52-58.

BLAXTER, K.L., GRAHAM, N. McC. and WAINMAN, F.W. (1959) Environmental temperature, energy metabolism and heat regulation in sheep. III The metabolism and thermal exchanges of sheep with fleeces. J. agric. Sci., Camb. 52, 41-49.

BOORMAN, K.N. (1980) Dietary constraints on nitrogen retention. In Protein Deposition in Animals. eds. P.J. Buttery and D.B. Lindsay, Butterworths, London Boston.

BRAMLEY, P.S., DENEHY, H.L. and NEWTON, J.E. (1976) The effect of different planes of nutrition before mating on the reproductive performance of Masham ewes. Vet. Rec. 99, 294-296.

BROCKMAN, R.P. (1978) Roles of glucagon and insulin in the regulation of metabolism in ruminants - A review Can. Vet. J., 19, 55-62.

BROCKMAN, R.P., BERGMAN, E.N., JOO, P.K. and MANNS, J.G. (1975) Effects of glucagon and insulin on net hepatic metabolism of glucose precursors in sheep. Am. J. Physiol. 229, 1344-1350.

BRODY, S. (1945) Bioenergetics and Growth - with special reference to the efficiency complex in domestic animals. Reinhold Publishing Corporation, New York USA.

CARTWRIGHT, G.A. and THWAITES, C.J. (1976a) Foetal stunting in sheep. 1. The influence of maternal nutrition and high ambient temperature on the growth and proportions of Merino foetuses. J. agric. Sci., Camb. 86, 573-580.

CASIDA, L.E., WOODY, A.L. and POPE, A.L. (1966) Inequality in function of the right and left ovaries and uterine horns of the ewe. J. Anim. Sci. 25, 1169-71.

CHRISTENSEN, R.K. and PRIOR, R.L. (1976) Influence of dietary protein and energy on reproductive performance and nitrogen metabolism in Finn-cross ewes. J. Anim. Sci. 43, 1104-1113.

CLOETE, J.H.L. (1939) Prenatal growth in the Merino sheep Onderstepoort J. Vet. Sci. 13, 417-558.

COOMBE, J.B., WARDROP, I.D. and TRIBE, D.E. (1960) A study of milk production of the grazing ewe, with emphasis on the experimental technique employed. J. agric. Sci., Camb. 54, 353-359.

COOP, I.E. (1962) Liveweight-productivity relationhsips in sheep, 1. Liveweight and reproduction N.Z. J. agric. Res. 5, 249-64.

COOP, I.E. (1964) Liveweight, flushing and ewe fertility. Proc. Ruaskura Farmer's Conf. 69-81.

COOP, I.E. (1966) Effect of flushing on reproductive performance of ewes. J. agric. Sci., Camb. 67, 305-323.

COOP, I.E. and CLARK, V.R. (1969) The influence of nutritional level in early pregnancy of the ewe. J. agric. Sci., Camb. 73, 387-394.

COWAN, R.T. (1980) Changes in body composition of ruminants during early lactation. PhD Thesis, University of Aberdeen.

COWAN, R.T., ROBINSON, J.J. and FRASER, C. (1979) Effect of protein content of the diet on feed intake and milk yield of ewes in early lactation. Abst. Anim. Prod. 28, 453.

COWAN, R.T., ROBINSON, J.J., GREENHALGH, J.F.D. and McHATTIE, I. (1979) Body composition changes in lactating ewes estimated by serial slaughter and deuterium dilution. Anim. Prod. 9, 81-90.

COWAN, R.T., ROBINSON, J.J., McHATTIE, I. and PENNIE, K. (1981) Effect of protein concentration in the diet on milk yield, change in body composition and efficiency of utilisation of body tissue for milk production in ewes. Anim. Prod. 33, 111-120.

CROKER, K.P., LIGHTFOOT, R.J. and MARSHAL, T. (1978) The fertility of Merino ewes fed high protein supplements at joining. Proc. Aust. Soc. Anim. Prod. 12, 250.

CROOKE, W.M. and SIMPSON (1971) Determination of ammonium in Kjeldahl digests of crops by an automated procedure. J. Sci. Fd. Agric. 22, 9-10.

CUMMING, I.A. (1972a) The effect of increasing and decreasing liveweight on ovulation and embryonic survival in Border Leicester x Merino ewes. Proc. Aust. Soc. Anim. Prod. 9, 192-198.

CUMMING, I.A. (1972b) The effect of nutritional restriction on embryonic survival during the first three weeks of pregnancy in the Perendale ewe. Proc. Aust. Soc. Anim. Prod. 9, 199-203.

CUMMING, I.A., RIZZOLI, D.J., CLARKE, J.D. and McPHEE, S.R. (1978) Fecundity of the fat ewe. Proc. Aust. Soc. Anim. Prod. 12, 261.

DAVIES, P.J., JOHNSTON, R.G. and ROSS, D.B. (1971) The influence of energy intake on plasma levels of glucose, non-esterified fatty acids and acetone in the pregnant ewe. J. agric. Sci., Camb. 77, 261-265.

DINGWALL, W.S. (1982) Studies on conception, embryo survival and the early growth of feotuses in prolific ewes. PhD Thesis, University of Aberdeen.

DONALD, H.P. and PUSER, A.F. (1957) Competition in utero between twin lambs. J. agric. Sci., Camb. 48, 245-249.

DONALD, H.P. and RUSSEL, W.S. (1970) The relationship between liveweight of ewe at mating and weight of newborn lamb. Anim. Prod. 12, 273-280.

DONEY, J.M. and GUNN, R.G. (1973) Progress in studies on the reproductive performance of hill sheep. HFRO 6th report 69-73.

DONEY, J.M., GUNN, R.G. and SMITH, W.F. (1973) Transuterine migration and embryo survival in sheep. J. Reprod. Fert. 34, 363-367.

DONEY, J.M. and MUNRO, Joan. (1962) The effect of suckling, management and season on sheep milk production as estimated by lamb growth. Anim. Prod. 4, 215-220.

DONEY, J.M., PEART, J.N., SMITH, W.F. and DUDA, F. (1979) A consideration of the techniques for estimation of milk yield by suckled sheep and a comparison of estimates obtained by two methods in relation to the effect of breed, level of production and stage of lactation. J. agric. Sci., Camb. 92, 123-132.

DONEY, J.M., SMITH, W.E. and GUNN, R.G. (1976) Effects of post mating environmental stress or administration of ACTH on early embryonic loss in sheep. J. agric. Sci., Camb. 87, 133-136.

EDEY, T.N. (1966) Nutritional stress and pre-implantation embryonic mortality in Merino sheep. J. agric. Sci., Camb. 67, 287-293.

EDEY, T.N. (1969) Prenatal mortality in sheep. A review. ABA 37 (2), 173-84.

EDEY, T.N. (1976) Nutrition and embryo survival in the ewe. Proc. N.Z. Soc. Anim. Prod. 36, 231-239.

EDEY, T.N. (1976) Embryo mortality. In Sheep breeding. Proceedings of the 1976 International Congress. Muresk and Perth, Western Australia, August 1976.

EDGAR, D.G. (1962) Studies on infertility in ewes. J. Reprod. Fert. 3, 50-54.

EGAN, A.R. and MACRAE, J.C. (1979) Amino acid catabolism and gluconeogenesis in the sheep. Ann. Rech. Vet. 10, 379-381.

ELSLEY, F.W.H., MACPHERSON, R.M., BALL, S.E. and PIRIE, I.M. (1968) Studies on the growth and development of the foetal pig. Anim. Prod. 10, 239. Abst.

EL-SHEIKH, A.S., HULET, C.V., POPE, A.L. and CASIDA, L.E. (1955) The effect of level of feeding on the reproductive capacity of the ewe. J. Anim. Sci. 14, 919-929.

EVERITT, G.C. (1964) Maternal undernutrition and retarded foetal development in Merino sheep. Nature, 201, 1341.

EVERITT, G.C. (1966) Maternal food consumption and foetal growth in Merino sheep. Proc. Aust. Soc. Anim. Prod. 6, 91-101.

EVERITT, G.C. (1967) Residual effects of prenatal nutrition on the postnatal performance of Merino sheep. Proc. N.Z. Soc. Anim. Prod. 27, 52-68.

EVERITT, G.C. (1968) Prenatal development of uniparous animals, with particular reference to the influence of maternal nutrition in sheep. In Growth and Development of Mammals, Ed. G.A. Lodge and G.E. Lamming. Proc. 14th Easter School in Agric. Sci. Univ. Nottingham. 1967, Publ. 1968 p. 131-157.

FAICHNEY, G.J. and WHITE, G.A. (1980) Urea synthesis by the sheep foetus. Proc. Nutr. Soc. Aust. 5

FERGUSON, J.A. (1975) Hay quality and the pregnant ewe. PhD Thesis, University of Edinburgh.

FINDLAY, A.L.R. (1970) Neural and behavioural interactions with lactation. In Lactation. The Univ. Nott. 17th Easter School in Agric. Sci., 1970 (ed. I.R. Falconer) London, Butterworths.

FLETCHER, I.C. (1971) Effects of nutrition, liveweight and season on the incidence of twin ovulation in South Australia Strong Wool Merino ewes. Aust. J. agric. Res. 22, 321-30.

FOOT, J.Z. and RUSSEL, A.J.F. (1979) The relationship in ewes between voluntary food intake during pregnancy and forage intake during lactation and after weaning. Anim. Prod. 28, 25-39.

FORBES, J.M. (1970) Voluntary food intake of pregnant ewes. J. Anim. Sci. 31, 1222-1227.

FORBES, J.M. (1977) Interrelationships between physical and metabolic control of voluntary food intake in fattening, pregnant and lactating mature ewes: a model. Anim. Prod. 24, 91-101.

FORBES, T.J. and ROBINSON, J.J. (1967) The effect of source and level of dietary protein on the performance of in-lamb ewes. Anim. Prod. 9, 521-530.

FUJIHARA, T. and TASAKI, I. (1980) The effect of dietary casein level on the concentration of plasma amino acids in goats sustained by abomasal feeding. Japanese Journal of Zootechnical Science, 51, 352-359.

GARDNER, R.W. and HOGUE, D.E. (1963) Studies on the TDN requirements of pregnant and lactating ewes. J. Anim. Sci. 22, 410-417.

GONZALEZ, J.S., ROBINSON, J.J., McHATTIE, I. and FRASER, C. (1982) The effect in ewes of source and level of dietary protein on milk yield, and the relationship between the intestinal supply of non-ammonia nitrogen and the production of milk protein. Anim. Prod. 34, 31-40.

GONZALEZ, J.S., ROBINSON, J.J., McHATTIE, I. and MEHREZ, A.Z. (1979) The use of lactating ewes in evaluating protein sources for ruminants. Proc. Nutr. Soc. 38; 145A.

GORDON, J.G. and TRIBE, D.E. (1951) The self-selection of diet by pregnant ewes. J. agric. Sci., Camb. 41, 187-190.

GRAHAM, N. Mc.C. (1964) Energy exchanges of pregnant and lactating ewes. Aust. J. Agric. Res. 15, 127-141.

GREGORY, P.W. and CASTLE, W.E. (1931) Further studies on the embryological basis of size inheritance in the rabbit. J. exp. Zool. 59, 199-

GREGORY, R.W. and GOSS, H. (1933a) The relation of sulphydryl concentration to size inheritance in the rabbit. Amer. Nat. 67, 180-

GREGORY, P.W. and GOSS, H. (1933b) Glutathione concentration and hereditary body size (II Glutathione concentration in non-nursed young of populations of rabbits differing in gentic constitution for adult size). J. exp. Zool. 66, 155-

GREGORY, P.W. and GOSS, H. (1933c) Glutathione concentration and hereditary size. (III The backbone of the large parent race) J. exp. Zool. 66, 335-

GUADA, J.A., ROBINSON, J.J. and FRASER, C. (1976) The effect of a reduction in food intake during late pregnancy on nitrogen metabolism in ewes. J. agric. Sci., Camb. 111-116.

GUNN, R.G. and DONEY, J.M. (1975) The interaction of nutrition and body condition at mating on ovulation rate and early embryonic mortality in Scottish Blackface ewes. J. agric. Sci., Camb. 85, 465-470.

GUNN, R.G. and DONEY, J.M. (1979) Fertility in Cheviot ewes 1. The effect of body condition at mating on ovulations rate and early embryo in North and South Country Cheviot ewes. Anim. Prod. 29, 11-16.

GUNN, R.G. DONEY, J.M. and RUSSEL, A.J.F. (1969) Fertility in Scottish Blackface ewes as influenced by body condition at mating and by post-mating nutrition. J. agric. Sci., Camb. 73, 289-294.

GUNN, R.G., DONEY, J.M. and RUSSEL, A.J.F. (1972) Embryo mortality in Scottish Blackface ewes as influenced by body condition at mating and by post-mating nutrition. J. agric. Sci., Camb. 79, 19-25.

GUNN, R.G., DONEY, J.M. and SMITH, W.F. (1979a) Fertility in Cheviot ewes. 2. The effect of level of pre-mating nutrition on ovulation rate and early embryo mortality in north and south Country Cheviot ewes in moderately good condition at mating. Anim. Prod. 29, 17-23.

GUNN, R.G., DONEY, J.M. and SMITH, W.F. (1979b) Fertility in Cheviot ewes. 3. The effect of level of nutrition before and after mating on ovulation rate and early embryo mortality in south Country Cheviot ewes in moderate condition at mating. Anim. Prod. 29, 25-31.

GUNN, R.G, DONEY, J.M. and SMITH, W.F. (1979c) The effect of time of mating on ovulation rate and potential lambing rate of Greyface ewes. Anim. Prod. 29, 277-82.

GUNN, R.G., SMITH, W.F., SENIOR, A.J., BARTHRAM, E. and SIM, D.A. (1983) Pre-mating pasture intake and reproductive responses in North Country Cheviot ewes in different body conditions. Anim. Prod. 36, 509 Abst.

HADJIPIERIS, G. and HOLMES, W. (1966) Studies on feed intake and feed utilisation by sheep. I. The voluntary feed intake of dry, pregnant and lactating ewes. J. agric. Sci., Camb. 66, 217-223.

HAFEZ, E.S.E. (1963) Symposium on Growth: Physio-genetics of prenatal and postnatal growth. J. Anim. Sci. 22, 779-791.

HAMMOND, Sir J. (1932) Growth and development of mutton qualities in the sheep. Oliver and Boyd, Edinburgh

HAMMOND, J. (1952) Farm Animals 2nd. ed. Arnold, London.

HEANEY, D.P. and LODGE, G.A. (1975) Body composition and energy metabolism during late pregnancy in the ad libitum fed ewe. Can. J. Anim. Sci. 55, 545-555.

HENNING, W.L. (1939) Prenatal and postnatal sex ratio in sheep. J. agric. Res. 58, 565-580.

HERNANDEZ, DE TEJAD, A., GOMEZ, A., TORRES, and BLAS, C.D.E. (1975) Relation between energy content of milk samples from Merino sheep and chemical composition. Anales Instituto Nacional de Investigaciones Agrarias, Produccion Animal 6, 69-75.

HOVE, K. and BLOM, A.K. (1976) Plasma insulin and growth hormone concentrations in pregnant sheep I. Diurnal variations in mid and late pregnancy. Acta Endocrinologia 82, 544-552.

HUGGETT, St. G. and HAMMOND, J. (1952) Phsyiology of the placenta In Marshall's Physiology of Reproduction ed. A.S. Parkes Vol 2 pp 127-311. Longmans, Green and Co, London.

HULET, C.V., VOIGTLANDER, H.N., POPE, A.L. and CASIDA, L.E. (1956) The nature of early season infertility in sheep. J. Anim. Sci. 15, 607-616.

HUNTER, G.L. (1956) The maternal influence on size in sheep. J. agric. Sci., Camb. 48, 36-60.

JOUBERT, D.M. (1956) A study of pre-natal growth and development in the sheep. J. agric. Sci., Camb. 47, 382-428.

KELLY, R.W. and ALLISON, A.J. (1979) Returns to service, embryonic mortality and lambing performance of ewes with one and two ovulations. In Sheep Breeding 2nd ed. pp 327-333. Eds. G.J.Tomes, D.E. Robertson and R.J. Lightfoot revised by W. Haresign, Butterworths, London.

KLOSTERMAN, E.W., BUCHANAN, M.L., BOLIN, D.W. and BOLIN, F.M. (1951) Levels and sources of protein in rations for pregnant ewes. J. Anim. Sci. 10, 257-265.

KNIGHT, T.W., OLDHAM, C.M. and LINDSAY, D.R. (1975) Studies in ovine fertility in agricultural regions in Western Australia: the influence of lupins (Lupinus angustifolius cv Uniwhite) at joining on reproductive performance of ewes. Aust. J. Agric. Res. 26, 567-575.

LAFFEY, N. and HART, D.S. (1959) Embryonic loss from late breeding season matings of ewes. N.Z.J. agric. Res. 2, 1159-1166.

LAIRD, A.K. (1966) Dynamics of embryonic growth. Growth 30, 263-275.

LANGLANDS, J.P., CORBETT, J.L., McDONALD, I. and PULLAR (1963) Estimates of energy required for maintenance by adult sheep. 1. Housed sheep. Anim. Prod. 5, 1-9.

LANGLANDS, J.P., CORBETT, J.L., McDONALD, I. and REID, G.W. (1963) Estimates of the energy required for maintenance by adult sheep. 2. Grazing sheep. Anim. Prod 5, 11-16.

LANGLANDS, J.P. and SUTHERLAND, H.A.M. (1968) An estimate of the nutrients utilised for pregnancy by Merino sheep. Br. J. Nutr. 22, 217-227.

LEMONS, J.A., ADCOCK III, E.W., JONES, M.D. Jr, NAUGHTON, M.A. MESCHIA, G. and BATTAGLIA, F.C. (1976) Umbilical uptake of amino acids in the unstressed foetal lamb. Journal of Clinical Investigation 58, 1428-1434.

LENG, R.A. (1976) Factors influencing net protein production by the rumen microbiota. Reviews in Rural Science 2, 85-91.

LEWIS, D. (1957) Blood-urea concentration in relation to protein utilisation in the ruminant. J. agric. Sci., Camb. 48, 438-446.

LIGHTFOOT, R.J., MARSHALL, T. and CROKER, K.P. (1976) Effects of rate and duration of lupin grain supplementation on ovulation and fertility of Merino ewes. Proc. Aust. Soc. Anim. Prod. 11, 5P.

LODGE, G.A. and HEANEY, D.P. (1975) Influence of feed allowance during pregnancy on reproductive performance of ewes and growth of suckled and artifically reared lambs. Can. J. Anim. Sci. 55, 533-544.

LOWMAN, B.G. (1970) Minimum N requirements of pregnant Clun Forest ewes. PhD Thesis, University of Reading.

LUSH, J.L., HETZER, H.O. and CULBERTSON, C.C. (1934) Factors affecting birth weights of swine. Genetics 19, 329-

McCANCE, J. (1959) The determination of milk yield in the Merino ewe. Aust. J. Agric. Res. 10, 839-853.

McCLELLAND, T.H. and FORBES, T.J. (1968) A study of the effect of energy and protein intake during late pregnancy on the performance of housed Scottish Blackface ewes. Res. Agric. Res. 17, 131-139.

McCLELLAND, T.H. and FORBES, T.J. (1971) A study of protein requirements of housed Scottish Blackface ewes during late pregnancy. Anim. Prod. 13, 643-651.

McDONALD, P., EDWARDS, R.A. and GREENHALGH, J.F.D. (1975) Animal Nutrition 2nd Edition. Longman, London and New York.

McDONALD, I., ROBINSON, J.J., FRASER, C. and SMART, R.I. (1979) Studies on reproduction in prolific ewes. 5. The accretion of nutrients in the foetuses and adnexa. J. agric. Sci., Camb. 92, 591-604.

MACKENZIE, A.J. and EDEY, T.N. (1975a) Short term under-nutrition and prenatal mortality in young and mature ewes. J. agric. Sci., Camb. 84, 113-117.

MACKENZIE, A.J. and EDEY, T.N. (1975b) Effects of premating undernutrition on oestrus, ovulation and prenatal mortality in Merino ewes. J. agric. Sci., Camb. 84, 119-124.

MAFF (1973) The Analysis of Agricultural Materials. Technical Bulletin No 27. HMSO London.

MAFF (1975) Energy Allowances and Feeding Systems for Ruminants. MAFF, DAFS, DANI. Tech. Bull. No 33. HMSO London.

MAYES, P. (1975) Metabolism of Carbohydrate. In Review of Physiological Chemistry. 15th Edition. Lange Medical Publications. ed. H.A. Harper. California.

MEAT AND LIVESTOCK COMMISSION (1982) Commercial Sheep Production Yearbook 1981-82. MLC Economics Livestock and Marketing Services 1982. MLC Bletchley, Bucks.

MILLS, S.E. and JENNY, B.E. (1979) Effects of high concentrate feeding and fasting on plasma glucocorticoids in dairy heifers. J. Anim. Sci., 48, 961-965.

MOIR, R.J. and HARRIS, L.E. (1962) Ruminal Flora studies in the sheep. X. Influence of nitrogen intake upon ruminal function. J. Nutr. 77, 285-298.

MOULE, G.R., BRADEN, A.W.H. and LAMOND, D.R. (1963) The significance of oestrogens in pasture plants in relation to animal production. Anim. Breed. Abstr. 31, 139-157.

MUNRO, J. (1955) Studies on the milk yield of Scottish Blackface ewes. J. agric. Sci. 46, 131-136.

NATIONAL RESEARCH COUNCIL (1975) Nutrient requirements of domestic animals No 5. Nutrient requirements of sheep 5th revised edition. National Academy of Sciences, Washington DC.

ØRSKOV, E.R., FRASER, C. and McDONALD, I. (1972) Digestion of concentrates in sheep. 4. The effects of urea on digestion, nitrogen retention and growth in young lambs. Br. J. Nutr. 27, 491-501.

ØRSKOV, E.R., REID, G.W. and McDONALD, I. (1981) The effects of protein degradability and food intake on milk yield and composition in cows in early lactation. Br. J. Nutr. 45, 547-555.

OWEN, J.B. (1957) A study of the lactation and growth of hill sheep in their native environment and under lowland conditions. J. agric. Sci., Camb. 48, 387-412.

PARR, R.A., CUMMING, I.A. and CLARKE (1982) Effects of maternal nutrition and plasma progesterone concentrations on survival and growth of the sheep embryo in early gestation. J. agric. Sci. 98, 39-46.

PARR, R.A., CUMMING, I.A., LAWSON, R.A.S., KERTON, D.J. and HARRIS, D.M. (1978) The influence of progesterone and nutrition on the sheep embryo. Proc. Aust. Soc. Anim. Prod. 12, 257.

PEART, J.N., DONEY, J.M. and SMITH, W.F. (1979) Lactation pattern in Scottish Blackface and East Friesland x Scottish Blackface cross-bred ewes. J. agric. Sci., Camb. 92, 133-138.

PEART, J.N., EDWARDS, R.A. and DONALDSON, L. (1972) The yield and composition of the milk of Finnish Landrace x Blackface ewes. I. Ewes and lambs maintained indoors. J. agric. Sci. 79, 303-313.

PRIOR, R.L. and CHRISTENSEN, R.K. (1976) Influence of dietary energy during gestation on lambing performance and glucose metabolism in Finn-cross ewes. J. Anim. Sci. 43, 1114-1124.

RATTRAY, P.V., GARRETT, W.N., EAST, N.E. and HINMAN, N. (1974) Growth, development and composition of the ovine conceptus and mammary gland during pregnancy. J. Anim. Sci. 38, 613-626.

RATTRAY, P.V., TRIGG, T.E. and URLICH, C.F. (1979) Energy exchanges in twin-pregnant ewes. Paper presented at the 8th Energy Metabolism Symposium. September 1979.

REID, R.L. and HINKS, N.T. (1962a) Studies on the carbohydrate metabolism of the sheep. XVII Feed requirements and voluntary feed intake in late pregnancy, with particular reference to prevention of hypoglycaemia and hyperketonaemia. Aust. J. Agric. Res. 13, 1092-1111.

REID, R.L. and HINKS, N.T. (1962b) Studies on the carbohydrate metabolism of the sheep. XVIII The metabolism of glucose, free fatty acids, ketones and amino acids in late pregnancy and lactation. Aust. J. Agric. Res. 13, 1112-1123.

REID, R.L. and HINKS, N.T. (1962c) Studies on the carbohydrate metabolism of sheep. XIX The metabolism of glucose, free fatty acids, and ketones after feeding and during fasting or undernourishment of non-pregnant, pregnant and lactating ewes. Aust. J. Agric. Res. 13, 1124-1136.

REILLY, P.E.B. and BLACK, A.L. (1973) Early effects of cortisol on glucose and alanine metabolism in adrenalectomised sheep. Am. J. Physiol. 225, 689-695.

REILLY, P.E.B. and FORD, E.J.H. (1974) The effects of betamethasone on glucose production and gluconeogenesis from amino acids in sheep. J. Endocrinol. 60, 455-461.

RICHARDSON, C. (1977) Morphological parameters of intrauterine growth retardation in the newborn lamb. Vet. Rec. 101, 151-152.

ROBINSON, J.J. (1977) Response of the lactating ewe to variation in energy and protein intake. Eur. Ass. Anim. Prod. 28th A Study Meeting, Brussels 512: 1-11.

ROBINSON, J.J. (1977) The influences of maternal nutrition on ovine foetal growth. Proc. Nutr. Soc. 36, 9-16.

ROBINSON, J.J. (1980) Energy requirements of ewes during late pregnancy and early lactation. Vet. Rec. 106, 282-284.

ROBINSON, J.J. (1981) Prenatal growth and development in the sheep and its implications for the viability of the newborn lamb. Livest. Prod. Sci. 8, 273-281.

ROBINSON, J.J. (1982) Pregnancy. In Sheep and Goat Production, World Animal Science C Production - System Approach. Vol 1 ed. I.E. Coop pp 103-118. Elsevier.

ROBINSON, J.J. and FORBES, T.J. (1966) A study of the protein requirements of the mature breeding ewe. Maintenance requirements of the non-pregnant ewe. Br. J. Nutr. 20, 263-72.

ROBINSON, J.J. and FORBES, T.J. (1967) A study of the protein requirements of the mature breeding ewe. 2. Protein utilisation in the pregnant ewe. Br. J. Nutr. 21, 879-891.

ROBINSON, J.J. and FORBES, T.J. (1968) The effect of protein intake during gestation on ewe and lamb performance. Anim. Prod. 10, 297-309.

ROBINSON, J.J. and FORBES, T.J. (1970) Studies on protein utilisation by ewes during lactation. Anim. Prod. 12, 601-610.

ROBINSON, J.J., FOSTER, W.H. and FORBES, T.J. (1969) The estimation of the milk yield of a ewe from body weight data on the suckling lamb. J. agric. Sci., Camb. 72, 103-107.

ROBINSON, J.J., FRASER, C. and BENNET, C. (1971) An assessment of the energy requirements of the pregnant ewe using plasma free fatty acid concentrations. J. agric. Sci., Camb. 77, 141-145.

ROBINSON, J.J., FRASER, C., CORSE, E.L. and GILL, J.C. (1970) The effect of pattern of protein intake and level of energy intake on the performance and nitrogen utilisation of the ewe. J. agric. Sci., Camb. 75, 403-411.

ROBINSON, J.J. and McDONALD, I. (1979) Ovine prenatal growth, its mathematical description and the effects of maternal nutrition. Ann. Biol. Anim. Bioch. Biophys. 19, 225-234.

ROBINSON, J.J., McDONALD, I., FRASER, C. and CROFTS, R.M.J. (1977) Studies on reproduction in prolific ewes. I Growth of the products of conception. J. agric. Sci., Camb. 88, 539-552.

ROBINSON, J.J., McDONALD, I., FRASER, C. and GORDON, J.G. (1980) Studies on reproduction in prolific ewes. 6. The efficiency of energy utilisation for conceptus growth. J. agric. Sci., Camb. 94, 331-338.

ROBINSON, J.J., McDONALD, I., McHATTIE, I. and PENNIE, K. (1978) Studies on reproduction in prolific ewes. 4. Sequential changes in maternal body during pregnancy. J. agric. Sci., Camb.

ROBINSON, J.J., McHATTIE, I., CALDERON CORTES, J.F. and THOMPSON, J.L. (1979) Further studies on the response of lactating ewes to dietary protein. Anim. Prod. 29, 257-269.

ROBINSON, J.J., SMART, R.I. and PENNIE, K. (1978) The energy requirements of twin-bearing ewes in late pregnancy and the extent of body tissue mobilisation. Paper given at BSAP Winter Meeting 1978. Anim. Prod. 26, 390-391.

ROSEN, F., KAISER, N., MAYER, M. and MILHOLLAND, R.J. (1976) Glucocorticoids: Receptors and mechanism of action in lymphoid tissues and muscle. Methods Cancer Res. 13, 67-99.

RUSSEL, A.J.F., DONEY, J.M. and GUNN, R.G. (1969) Subjective assessment of body fat in live sheep. J. agric. Sci., Camb. 72, 451-454.

RUSSEL, A.J.F., DONEY, J.M. and REID, R.L. (1967a) The use of biochemical parameters in controlling nutritional state in pregnant ewes, and the effect of under-nourishment during pregnancy on lamb birth weight. J. agric. Sci., Camb. 68, 351-358.

RUSSEL, A.J.F., DONEY, J.M. and REID, R.L. (1967b) Energy requirements of the pregnant ewe. J. agric. Sci. Camb. 68, 359-363.

RUSSEL, A.J.F., FOOT, J.Z., WHITE, I.R. and DAVIES, G.J. (1981) The effect of weight at mating and of nutrition during mid-pregnancy on the birth weight of lambs, from primiparous ewes. J. agric. Sci., Camb. 97, 723-729.

RUSSEL, A.J.F., MAXWELL, T.J. and FOOT, J.Z. (1973) Nutrition of the hill ewe during late pregnancy. HFRO 6th Rep. pp43-56.

RUSSEL, A.J.F., MAXWELL, T.J., SIBBALD, A.R. and McDONALD, D. (1977) Relationships between energy intake, nutritional state and lamb birth weight in Greyface ewes. J. agric. Sci., Camb. 89, 667-673.

RUTTER, W., BROADBENT, P.J. and LAIRD, T.R. (1976) A note on the pattern of concentrate feeding to ewes in late pregnancy. Anim. Prod. 23, 421-424.

SCOTTISH AGRICULTURAL COLLEGES (1978) Nutrient Allowances for Cattle and Sheep. Publication No 29.

SHEEHAN, W. and LAWLOR, M.J. (1972) Energy supplementation of silage for ewes in late pregnancy. Anim. Prod. 15, 29-37.

SHEVAH, Y., BLACK, W.J.M. and LAND, R.B. (1975) The effects of nutrition on the reproductive performance of Finn x Dorset ewes. J. Reprod. Fert. 45, 283-288.

SLATER, J.S. and MELLOR, D.J. (1972) Effect of plane of nutrition on maternal and foetal amino acid concentrations in the sheep. Biochemical Journal 129, 12P (Abstr.)

SLATER, J.S. and MELLOR, D.J. (1977) Effects of starvation surgery and infusion of adrenocorticotrophin on plasma amino acid concentrations in the pregnant ewe. Res. Vet. Sci. 22, 95-100.

SPEEDY, A.W., BLACK, W.J.M. and FITZSIMONS, J. (1983) The effect of different management actions on the performance of the grassland sheep flock. J. agric. Sci., Camb. 101 In Press.

STEEL, J.W. and LENG, R.A. (1973a) Effects of plane of nutrition and pregnancy on gluconeogenesis in sheep. 1. The kinetics of glucose metabolism. Br. J. Nutr. 30, 451-473.

STEEL, J.W. and LENG, R.A. (1973b) Effects of plane of nutrition and pregnancy on gluconeogenesis in sheep. 2. Synthesis of glucose from ruminal propionate. Br. J. Nutr. 30, 475-489.

STEGEMAN, J.H.J. (1974) Placental development in the sheep and its relation to foetal development. A qualitative and quantitative, anatomic and histologic study. Fjid tot die Dierk. 44, 3-72.

STRUEMPLER, A.W. and BURROUGHS, W. (1959) Stilboestrol feeding and growth hormone stimulation in immature ruminants. J. Anim. Sci. 18, 427-436.

SYKES, A.R. and FIELD, A.C. (1972a) Effects of dietary deficiencies of energy, protein and calcium on the pregnant ewe. III Some observation on the use of biochemical parameters in controlling energy undernutrition during pregnancy and on the efficiency of utilisation of energy and protein for foetal growth. J. agric. Sci., Camb. 78, 127-133.

SYKES, A.R. and FIELD, A.C. (1973) Effects of dietary deficiencies of energy, protein and calcium on the pregnant ewe. IV Serum total protein, albumin, globulin, transferrin and plasma urea levels. J. agric. Sci., Camb. 80, 29-36.

TAGARI, H., DROR, Y., ASCARELLI, I. and BONDI, A. (1964) The influence of elvels of protein and starch in rations of sheep on the utilisation of protein. Br. J. Nutr. 18, 333-356.

TAPLIN, D.E. and EVERITT. G.C. (1964) The influence of prenatal nutrition on postnatal performance of Merino lambs. Proc. Aust. Soc. Anim. Prod. 5, 72-81.

THOMPSON, P.D., PAAPE, M.J. and SMITH, J.W. (1973) Residual milk yield as affected by dose and time of injection of oxytocin. J. Dairy Res. 40, 221-227.

THOMSON, A.M. and THOMSON, W. (1948-49) Lambing in relation to the diet of the pregnant ewe. Br. J. Nutr. 2, 290-305.

THWAITES, C.J. (1967) Embryo mortality in the heat stressed ewe.I The influence of breed. J. Reprod. Fert. 14, 5-14.

TORELL, D.T., HUME, I.D. and WEIR, W.C. (1972) Effect of level of protein and enrgy during flushing on lambing performance. J. Anim. Sci. 34, 479-482.

TRENKLE, A.H. (1980) Amino acid metabolism and hormonal control during growth. In Digestive Physiology and Metabolism in Ruminants, pp 505-522. Proc. 5th Int. Symp. on Ruminant Physiology ed. Y. Ruckebusch and P. Thivend.

TRENKLE, A. and TOPEL, D.G. (1978) Relationships of some endocrine measurements to growth and carcass composition of cattle. J. Anim. Sci. 46, 1604-1609.

TYRRELL, R.N., GLEESON, A.R., FERGUSON, B.D., HALLORAN, W.J. and KILGOUR (1979) Evidence and confirmation of late embryo loss in a flock of Merino ewes. In Sheep Breeding 2nd ed. pp 327-333. eds. G.J. Tomes, D.E. Robertson and R.J. Lightfoot. Revised by W. Haresign, Butterworths.

VALDEZ ESPINOSA, R., ROBINSON, J.J. and SCOTT, D. (1977) The effect of different degrees of food restriction in late pregnancy on nitrogen metabolism in ewes. J. agric. Sci., Camb. 88, 399-403.

VIPOND, J.E. (1979) Effect of clipping and diet on intake and performance of housed pregnant and lactating ewes. Anim. Prod. 28, 451-452.

WAGNER, J.F. and VEENHUIZEN, E.L..(1978) Growth performance, carcass deposition and plasma hormone elvels in wether lambs when treated with grwoth hormone and thyroprotein. J. Anim. Sci., Suppl. 1, 47, 397 (Abstr.)

WALLACE, A.L.C. and BASSET, J.M. (1966) Effect of growth hormone on plasma insulin concentration in sheep. Metabolism 15, 95-97.

WALLACE, L.R. (1948a) The growth of lambs before and after birth in relation to the level of nutrition. Part 1. J. agric. Sci., Camb. 38, 93-153.

WALLACE, L.R. (1948b) The growth of lambs before and after birth in relation to the level of nutrition. Part II. J. agric. Sci., Camb. 38, 243-302.

WALLACE, L.R. (1948c) The growth of lambs before and after birth in relation to the level of nutrition. Part III. J. agric. Sci., Camb. 38, 367-401.

WALLACE, L.R. (1961) Influence of liveweight and condition on ewe fertility. Proc. Ruakura Farmer's Conf. 14-25.

WALLACE, A.L.C. and BASSETT, J.M. (1966) Effect of sheep growth hormone on plasma insulin concentration in sheep. Metabolism 15, 95-97.

WALTON, A. and HAMMOND, J. (1938) The maternal effects on growth and conformation in Shire horse - Shetland pony crosses. Proc. R. Soc. Lond (B), 125, 311-316.

WESTON, R.H. (1979) Digestion during pregnancy and lactation. Ann. Rech. Vet. 10, 442-444.

WHITTEMORE, C.T., MOFFAT, I.W. and TAYLOR, A.G. (1976) Evaluation by digestibility, growth and slaughter of microbial cells as a source of protein for young pigs. J. Sci. Fd. Agric. 27, 1163-1170.

WILLIAMS, H.L., HILL, R. and ALDERMAN, G. (1965) The effects of feeding kale to breeding ewes. Br. Vet. J. 121, 2-17.

YEATES, (1958) Foetal dwarfism in sheep - an effect of high atmospheric temperature during gestation. J. agric. Sci., Camb. 51, 84-89.

YOUNIS, A.A., AL-KAMALI, A.A. and EL-TAWIL, E.A. (1978) Effect of flushing of Awassi and Hamdani ewes. Wrld. Rev. Anim. Prod. 14(2) 41-48.

APPENDIX 1.

CALCULATION OF FEEDING ALLOWANCES FOR MAINTENANCE

Ewes were grouped in 5 kg weighted intervals , the mean liveweight of each group being used to calculate the allowance from the MAFF (1975) equation: $M_m = 1.4 + 0.09W$ for ewes indoors (where M_m is the metabolisable energy requirement for maintenance (MJ), and W is the liveweight of the ewe (kg)). Ten feeding allowances were obtained.

Calculation of feeding allowances post-mating

Allowances were calculated using an energy value for liveweight of 25 MJ/kg* (Edwards, R.A., personal communication). Efficiency of utilisation of energy for maintenance (K_m) was taken to be 0.7 and for growth (kg) to be 0.4 (MAFF, 1975). The H_2 ewes required 3.5 MJ ($\frac{56g \times 25 \text{ MJ/kg}}{1000}$ /0.4) dietary energy above maintenance, while the L_2 ewes required 2 MJ ($\frac{56g \times 25 \text{ MJ/kg}}{1000}$/0.7) dietary energy less than the maintenance allowance.

The basic maintenance allowance was adjusted for ewe liveweight at mating. Ewes were divided into groups of a 10 kg weight range in each of their groups = H_1H_2, H_1L_2, L_1H_2 and L_1L_2. Mean liveweight was used to calculate maintenance allowance to which 3.5 MJ was added or 2 MJ deducted for H_2 and L_2 groups respectively.

---

* 25.5 MJ/kg is value of liveweight change during pregnancy ARC (1980).

APPENDIX 2

ME allowances published by MAFF (1975) had come into question. The rations were calculated on the basis of data from a series of papers on foetal growth from Robinson, McDonald, Fraser and Crofts (1977), Robinson, McDonald, McHattie and Pennie (1978); McDonald, Robinson, Fraser and Smart (1979) and Robinson, McDonald, Fraser and Gonzalez (1980).

Maternal energy requirement for maintenance was 0.4 MJ/kg $^{0.75}$ giving a requirement of 10.09 MJ ME/day for 74 kg ewes (mean liveweight at mating).

To obtain a negative energy balance the maintenance requirement was reduced by 0.3.

Once allowance had been calculated the full allowance for a single or twin lamb at a certain stage of pregnancy was added and the ration allocated accordingly.

Not all the litter size determinations were accurate, and individual intakes were calculated finally. The second table gives the plan of allowances.

Table 2.1A

Days	Energy Deposition Twins		Energy requirement of twins (13-14% efficient)		Total ewe requirement	
	Singles	Twins	Singles	Twins	Singles	Twins
88	0.16	0.27	1.2	2.0	11.3	12.1
102	0.47	0.45	2.0	3.3	12.1	13.4
116	0.40	0.67	3.0	5.0	13.1	15.1
130	0.54	0.90	4.0	6.7	14.1	16.8
144	0.67	1.12	5.0	8.3	15.1	18.4

Calculated using an estimated birth weight

Table 2.2A Rations for Greyface ewes in late pregnancy

Treatment	No of Lambs		Weeks before lambing 6		5	4	3	2	1
HEHP	2	Conc A + B	110A* + 40B*	220A + 80B	400A + 135B	825A + 275B	785 + 390	810 + 405	935 + 465
		Hay	800	700	500	400	400	400	400
	1	Conc A + B				690A + 230B	650 + 325	705 + 350	740 + 370
		Hay				400	400	400	400
LEHP	2	Conc A	125A	250A	450A	835	900	1035	1125
		Hay	800	700	400	400	400	400	400
	1	Conc A				655	700	780	835
		Hay				400	400	400	400
LELP	2	Conc B	125B	250B	450B	835	900	1015	1100
		Hay	800	700	500	400	400	400	400
	1	Conc B				655	700	765	820
		Hay				400	400	400	400

* A - high protein concentrate; B - low protein concentrate

***** ANALYSIS OF VARIANCE *****

VARIATE: V(97) TOTAL - GROSS ENERGY CONTENT

SOURCE OF VARIATION	DF(MV)	SS	SS%	MS	VR
UNITS STRATUM					
PR	1	3505.7	36.82	3505.7	28.147
ENPO	2	652.8	6.86	326.4	2.620
PR.ENPO	2	87.4	0.92	43.7	0.351
RESIDUAL	47(8)	5854.0	61.49	124.6	
TOTAL	52	10099.8	106.06	194.2	
GRAND TOTAL	52	10099.8	106.06		

ESTIMATED GRAND MEAN 45.0
TOTAL NUMBER OF OBSERVATIONS 61
NUMBER OF MISSING VALUES 8
MAXIMUM NUMBER OF ITERATIONS 3

UNIT NUMBER	ESTIMATED VALUE
8	58.7
10	58.7
13	51.7
19	51.7
23	47.8
27	47.8
30	47.8
49	37.9

***** TABLES OF MEANS *****

VARIATE: V(97) TOTAL - GROSS ENERGY CONTENT

GRAND MEAN 45.0

PR	HPR	LPR
	52.9	37.7
REP	29	32

ENPO	HEHP	LEHP	LELP
	49.2	44.4	41.2
REP	20	21	20

	ENPO	HEHP	LEHP	LELP
PR				
HPR		58.8	51.7	47.8
	REP	10	10	9
LPR		40.5	37.9	35.1
	REP	10	11	11

***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****

TABLE	PR	ENPO	PR ENPO	
REP	UNEQUAL	UNEQUAL	UNEQUAL	
SED		3.53	5.26X	MIN REP
	2.86	3.49	5.02	MAX-MIN
		3.44X	4.76	MAX REP

(NO COMPARISONS IN CATEGORIES WHERE SED MARKED WITH AN X)

(NOT ADJUSTED FOR MISSING VALUES)

***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****

STRATUM	DF	SE	CV%
UNITS	47	11.16	24.8

101 'CLOSE'
******* END OF FOET142 AT LINE 98 USED 6591 LEFT 9793